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Journal Section
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JANUARY
1940

DIRECTORY
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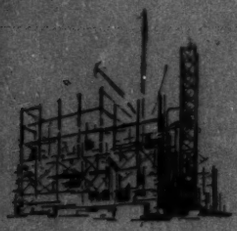
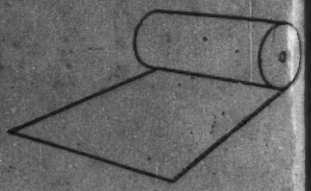
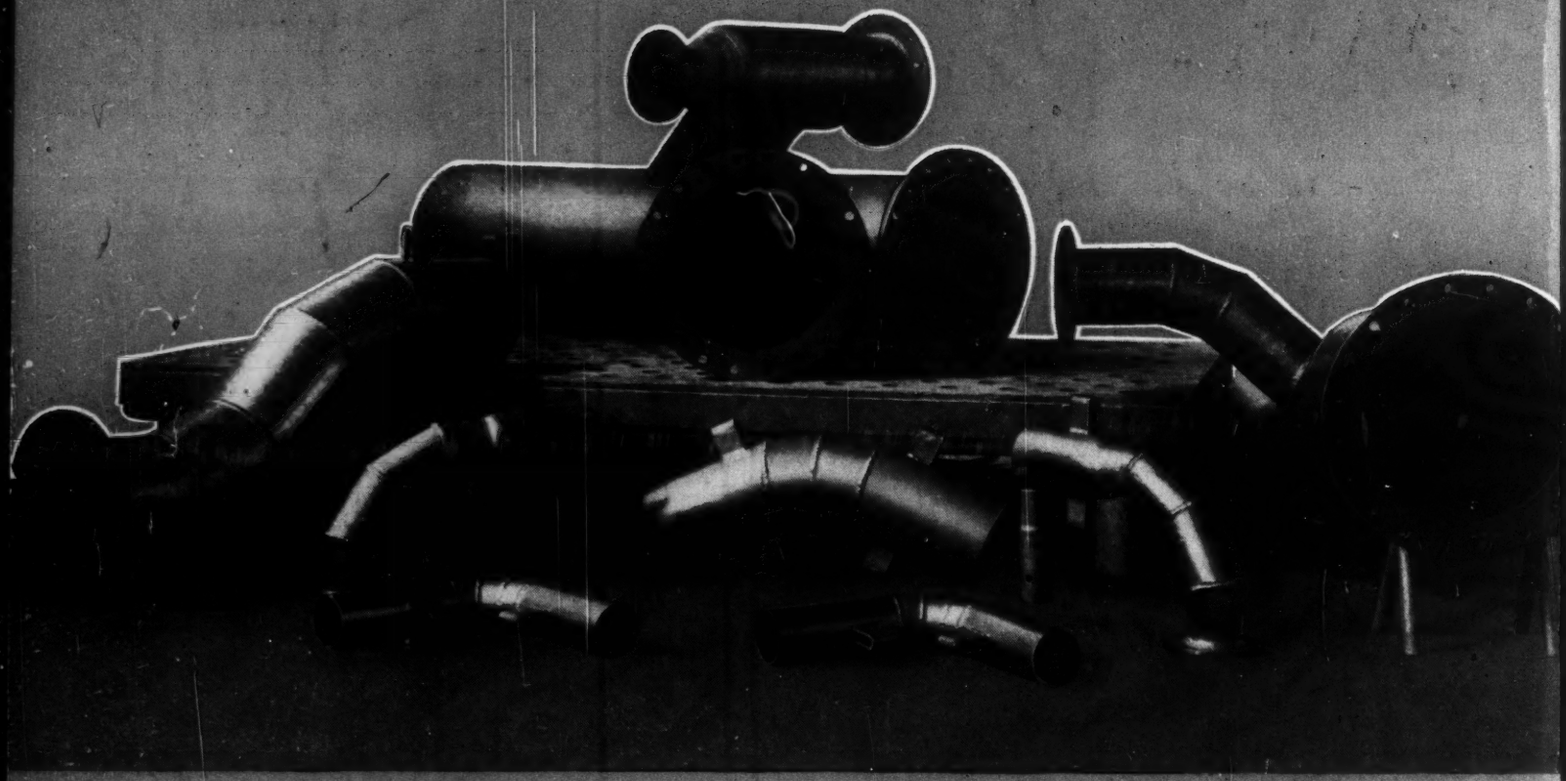
Paper Manufacturer Cuts Time

BETWEEN INVESTMENT AND RETURN







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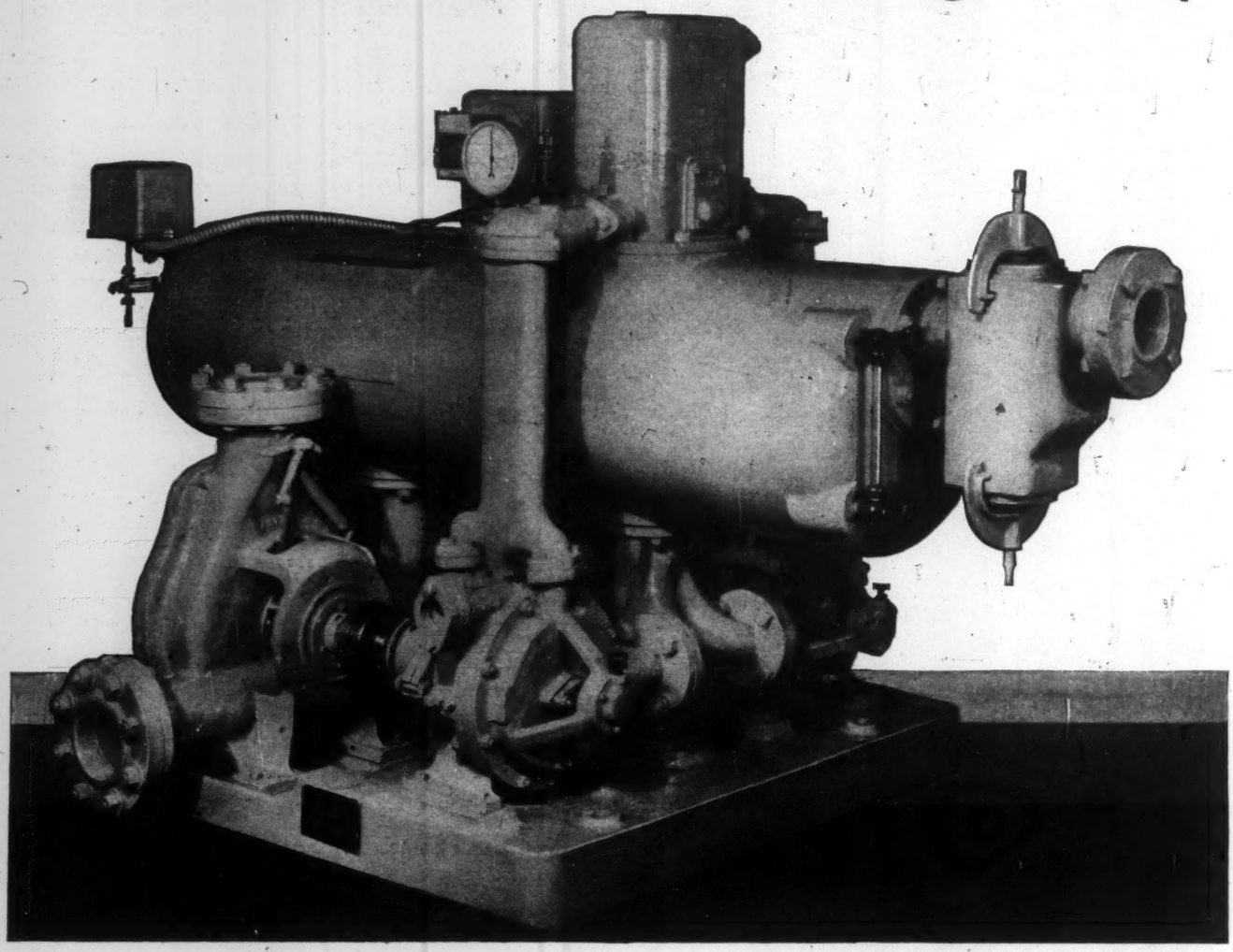
Where Heat Must Not Fail— Install this SAFE Heating Pump!



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THE EDITOR'S PAGES

DODGE ESTIMATES 1940 CONSTRUCTION RISE; TIME IS RIPE FOR PLANT MODERNIZATION

While the impact of the European war upon our whole economy is being felt already and is likely to be felt in numerous other ways as the war continues, it has become increasingly evident since September 1 that the course of events in this country will vary in many important particulars from the pattern of 1914-1918, according to Thomas S. Holden of F. W. Dodge Corp. at the recent construction industry conference of the Chamber of Commerce of the United States. While a dusting off of 25 year old charts and statistical record books has some value in giving a perspective view of the present situation, it does not give us a sure guide for the future; the future is just where it always has been—ahead of us and not behind us. This war itself is different from the other one, the attitude of the American people is radically changed, and our economic system itself has not stood still since 1914, he said.

It begins to look as though the menace of rapidly rising commodity prices and construction costs has been, at least temporarily, averted, he continued. General business and industrial activity, employment, and national income will average substantially higher in 1940 than in 1939, it appears. Increased activity in general industry and business is vitally important as a sustaining base for increased private construction. In the absence of population pressure of nineteenth century intensity, absence of any rapidly expanding industry comparable in scope with railroads or automobiles, and the absence of any great shortage of shelter, a mere desire for better shelter must be accompanied by generally augmented purchasing power, in order to be translated into an active and effective demand. Increased residential building is, at this moment, as dependent on increased industrial and business activity as industrial and commercial building. Fortunately, the indications seem favorable for increased activity in 1940 in all three of these important classes of private building operations.

It seems likely that increased private building volume will tend toward concentration in the busiest industrial centers, those which are likely to be more fully employed and more prosperous, Mr. Holden said. In estimating the extent of increased private building that may take place next year, it is necessary to give some weight to the possibility of a temporary business setback in the early months, the possibility of peace in Europe, and the fact that 1940 will be an election year.

After weighing these possible deterrents against the favorable factors, the Dodge statistical staff conservatively appraises the probable 1940 increase in private building and engineering expenditures at 10 to 15 per cent over 1939. The dollar estimates actually work out with an increase of 11½ per cent. This increase would include increased activity in commercial and industrial building, one- and two-family houses, and privately owned utilities. The one important class of private construction for which Dodge has estimated a decline consists of apartment houses. However, any decline in private apartment building that takes place is apt to be moderate and will certainly be much more than offset by multiple dwellings built under the USHA public housing program.

A summary of the F. W. Dodge Corp's. 1940 estimates by classes, the figures being based on dollar volumes of contracts in the 37 eastern states, was given by Mr. Holden as follows:

Commercial building: an increase of 16 per cent over 1939.

Manufacturing Buildings: an increase of 41 per cent.

All other non-residential buildings (principally public and institutional buildings): a decline of 15 per cent; hospitals are expected to increase, religious buildings to be built in the same volume as in 1939, and the other classes to decline.

Residential building: a 5 per cent increase in private residential and a 65 per cent increase in public residential building, netting a 14 per cent increase in all residential building. Large-type residential buildings (apartments and hotels, including both privately and publicly financed) are estimated to increase about 26 per cent; one- and two-family houses are estimated to increase about 9 per cent. New family dwelling units would increase in about the proportion of total dollar residential volume, 14 per cent.

Heavy engineering construction (public works and utilities): the total volume is estimated at practically the same as 1939, the net result of moderately increased highway construction, sizably increased electric utility construction, and declines in all other classes.

Current international uncertainties and the resulting difficulty of predicting commodity, raw material, or manufactured goods prices, make today the most propitious time in the past decade for increasing plant efficiency through modernization, declared Stuart M. Crocker, General Electric executive, in an address before the conference. "In times like these," he said, "modernization's economies are more important than they were last year, or the year before that—or perhaps than they will be next year. In fact, plant modernization is the current number one problem for industrial executives."

He defined plant modernization as "building the physical plant to the point where it is best suited to the product, plus the managerial way of thinking that must exist if a profitable plant is to be maintained. Altogether industrial modernization is the inseparable accompaniment to management that can't be caught napping."

Management can do little to affect raw material prices, taxes, interest, depreciation and many of the other costs of doing business, he pointed out, but it can seek production efficiency.

NEW TUBE MILL IN YOUNGSTOWN

A new tube mill for making ½ in. to extra heavy 3 in. butt welded pipe in any lengths from 1 to 45 ft by the Fretz-Moon process has been completed and put into operation by Republic Steel Corp. in Youngstown. It is to be followed immediately with a second similar unit, it was announced.

These two mills will use a continuous butt weld process in which the skelp is formed in a forming mill rather than being drawn through a bell die. In the manufacturing of tubes by this process, the skelp is brought to the mill in coils varying in length from 300 to 1200 ft. The skelp is uncoiled, passed through a roller leveler, and the end of each new coil electrically welded to the trailing end of the preceding coil. This makes one continuous strip to be charged into the furnace.

ST. LOUIS STORE AIR CONDITIONS

An order for a complete 600 ton air conditioning system for the entire Famous Barr Co., St. Louis department store, was announced last month by E. T. Murphy, vice-president in charge of marketing, Carrier Corp. The $700,000 installation will air condition the store, fifth largest in the United States, completely from basement to roof.

The air conditioning system will cleanse and remove the excess moisture from 1,000,000 cfm of air, which will be pumped through four miles of duct to maintain comfortable conditions over more than 18 acres of floor space.

1940 TO BE A NOTABLE CENSUS YEAR

To that famous pair of bosom pals, death and taxes, might be added a third individual who also rolls around at regular intervals in the life of every American—the census enumerator. This year, 1940, is a notable census year in that not a single individual, farm, or home, and hardly a commercial or industrial establishment in the entire United States, will escape the enumerator's call. Consulting engineers, contractors, plant and building engineers, architects, and others concerned with the design, installation, operation or maintenance of heating, piping and air conditioning systems, fall into at least one and perhaps more of the 1940 census subjects.

The sixteenth decennial census—to be taken this year, certain phases of which have already been started—will make nationwide inquiries into business and manufactures, mines and quarries, population, occupations, employment, housing, agriculture, drainage, and irrigation. The four first-named enumerations begin early in January, while the censuses of population and agriculture, etc., will get under way in April.

Engineers who are strictly consultants will not be canvassed, nor will other professional men (except under the censuses of population). But all establishments engaged in the manufacture, sale, installation or maintenance of building equipment or buildings are now being enumerated under the appropriate divisions.

Construction companies, enumerated under the census of business, are being asked for basic facts concerning their operations for 1939. They are each required to describe their establishments, type of organization, specific kind of business (general contractor, heating and piping, air conditioning, insulating, sheet metal, electrical, etc.), dollar value of contracts or orders, types of work performed (new or old buildings, public, private, repairs and maintenance, heavy construction, etc.), work performed by location, materials used, mechanical equipment installed, merchandise sold, and so on.

Special schedules are being supplied to (and separate statistics will later be available for) firms engaged in production of oil burners (domestic and industrial); power boilers and associated products; steam and hot water heating apparatus and steam fittings; heating equipment (except electric) not elsewhere classified; stoves, ranges, water heaters, and warm air furnaces (except electric); mechanical measuring instruments; generating, distribution, and industrial apparatus (electrical), and apparatus for incorporation in manufactured products; air compressors and pumping equipment; blowers—exhaust and ventilating fans; mechanical stokers, domestic and industrial; refrigeration machinery and equipment; and complete air conditioning units. The census of manufactures will also cover the production of building insulation; gypsum products; asbestos products; steam packing, pipe and boiler covering, etc.

The 1940 census of population, beginning in April, will also include the censuses of occupations, employment and housing. The housing inquiry, being made for the first time on a nationwide scale, will unearth significant facts pointing to age and condition of dwelling houses in the United States, conveniences available (heating equipment and fuel used, presence of water, type of plumbing, installation of electricity, etc.). From the various 1940 figures, current comparisons will easily be made as to status of building and allied industries in all parts of the country, the need for repairs or new construction, and whether or not a given section can financially "stand" improvements that are indicated.

EMPLOYEES TO SHARE COMPANY'S FORTUNES

A salary plan under which every salaried employee will share in the fortunes of the company has been introduced by Carrier Corp., according to an announcement by J. I. Lyle, president. Features of the plan include: (1) The net income or loss upon which increases or deductions are based is determined on a 12 months profit and loss record. (2) While increases are effective immediately (dependent upon earnings) no automatic deductions will be made under this plan during the first year the plan is in effect. (3) There is no minimum salary level below which the plan is not fully effective. (4) Any profitable operations are reflected in the salaries as well as in benefits to stockholders. (5) There is no minimum earning figure under which the plan is not operative.

The plan is the result of a nine month study and field survey by James A. Bentley, vice-president in charge of finance.

$200,000 AWARDS TO BE MADE

A 2½ year program of scientific study which will culminate in payment of $200,000 in awards has been announced by the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio. The 458 awards are established for studies bringing out benefits of a social, economic or commercial nature, such as reduction or elimination of hazards to safety and health, greater availability of comforts and conveniences through reduced prices, greater utility and durability of machines and structures as well as industrial benefits such as cost savings and other advantages in manufacture, fabrication or construction.

Studies encouraged with a view to creating such benefits will concern machines, products and structures of all types including heating, piping and air conditioning equipment. The "first grand award," which will be paid for the best progress report submitted, will total $13,700.

NEW METHOD OF RATING HEATING BOILERS

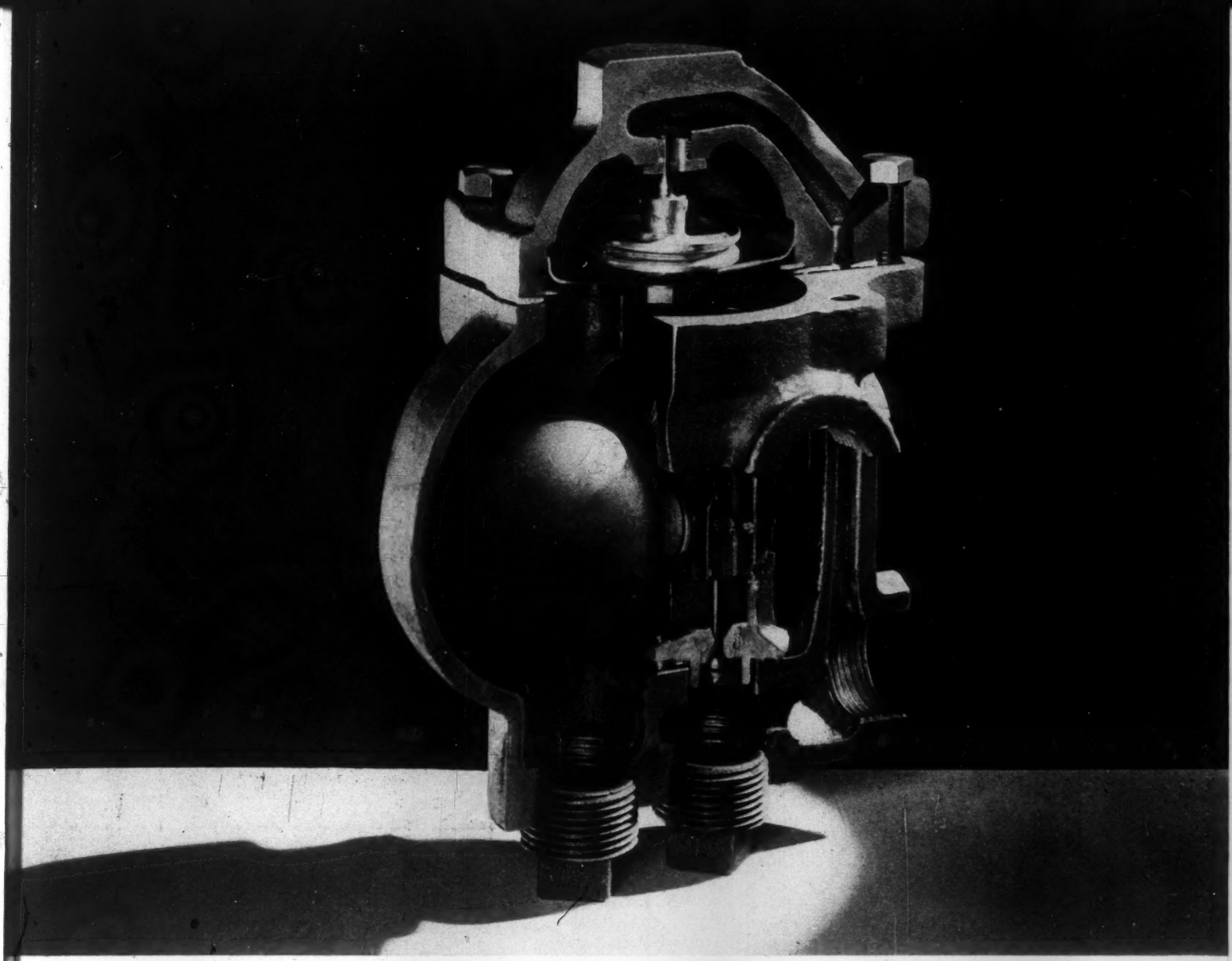
The Institute of Boiler and Radiator Manufacturers, 60 E. 42nd St., New York, N. Y., whose members are manufacturers of cast iron low pressure heating boilers and cast iron radiators, has adopted a common yardstick for measuring output based on actual boiler performance rather than on dimensions for boilers having grate widths not exceeding 20 in.

The term "IBR rating" will mean that the manufacturer has measured the output of his boiler according to an approved formula, and that the test data on which such rating is based have been reviewed by the institute and a license for use of such rating has been issued. Ratings will be expressed in terms of (1) gross IBR output in Btu; (2) net IBR rating in Btu; and (3) net IBR rating—sq ft of steam and water. The term "net IBR rating" means the gross IBR output less allowances for piping and pickup.

AIR HYGIENE GROUP MEETS

Tuned to the theme that "healthy workers make for healthy business," the fourth fall meeting of Air Hygiene Foundation was held at its headquarters, Mellon Institute, Pittsburgh, on November 14-15. More than 250 persons (a new high), representing 101 companies, attended.

Virtually all aspects of industrial health work were covered, ranging from the interests of top management to problems confronting the physician, engineer and safety director. Prof. Philip Drinker, chairman of the foundation's preventive engineering committee, described the two projects at Harvard: (1) investigation of the characteristics of electroplating tanks, baths and vats using toxic solvents and liquids to provide a rational basis of design; (2) determination of the most dangerous size range of dust particles in order "to focus our efforts particularly against them," as in the design of respirators and other dust capturing equipment.



The Webster Series "79" Trap is a float and thermostatic trap for process pressure service. Two sizes—¾" and 1". Four pressure classifications—ranging from 15 to 150 lbs. per sq. in. Rugged, built for heavy duty, yet light enough to be mounted in pipe line without other support. Water of condensation is passed through float-controlled seat opening . . . the *outward*-opening valve keeps the line clear. Stainless steel water valve with renewable stainless steel seat. Float is copper. Air and non-condensible gases are continuously discharged through thermostatic by-pass at top of trap. Thermostatic unit is Monel Metal with stainless steel valve piece which seats on renewable stainless-insert seat. Housing and cover are cast-iron.

"—has what it takes"

When large volumes of hot condensation threaten to impair the operation of equipment using steam in the 15-150 lb. range, architects, engineers and heating contractors recommend the Webster Series "79" Trap.

The float-controlled *outward*-opening water valve in the Webster "79" Trap assures quick, free and complete discharge of hot condensate. The thermostatic unit assures continuous discharge of air and non-condensible gases.

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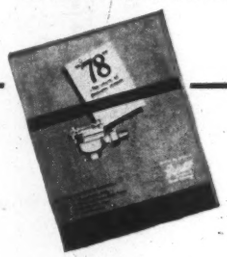

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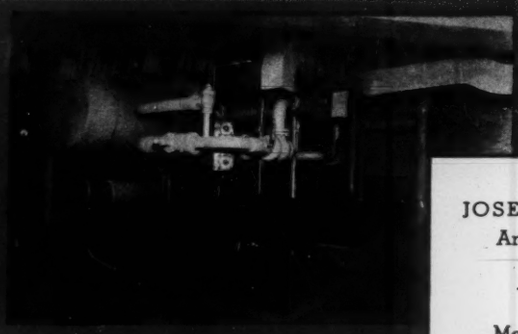

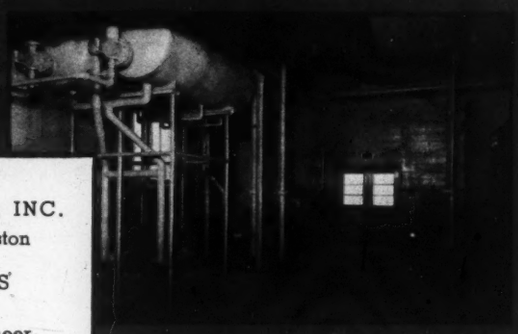

JOSEPH FINGER, INC.
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A. F. BARNES
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Mechanical Engineer

The emphasis which architects are today placing on the proper selection of materials for corrosive services is illustrated not only by the number of new buildings using wrought iron—but also by the number of services in each building for which wrought iron is used.

In the new City Hall, Houston, Texas, steam supply and return lines, fire lines, lines from house pump in basement to tank on roof, and cooling and chilled water lines in the air conditioning system were all Byers Wrought Iron. Records of the life of wrought iron in similar services, and under similar conditions, definitely confirm the soundness of this choice.

The variety of corrosion problems encountered, and the variety of materials offered to meet them, make the problem of materials selection a real problem. We will be glad to help you with its solution, as we have helped and are helping many other architects. If you will write, outlining the specific conditions, our Engineering Service Department will (1) Determine the probable types of corrosion involved; (2) Relate these to similar conditions encountered elsewhere; (3) Interpret the results in the light of 76 years' experience with corrosion problems; and (4) Make recommendations . . . supported by service records. We will be glad to send you a copy of our bulletin, "Wrought Iron in Piping Systems."

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Heating · Piping and Air Conditioning

Vol. 12, No. 1 • *January, 1940*

Air Conditioning Plays Wartime Rôle in Ordnance Manufacturing Processes

By Harry Boyd Matzen*

AT the outbreak of the last world war, air conditioning and refrigeration was still in its infancy, as compared to today. It received a tremendous impetus during the war in connection with the manufacture of clothing, foods, confections, airplanes and of great importance, at that moment, of ordnance, and other necessities.

As a peace-loving nation our country had no large storage of ordnance and no adequate facilities such as manufacturing plants to meet the immediate need of supplying a million soldiers at the front. However, science had made rapid advances in chemistry and physics, and our methods of manufacturing had developed to such a stage in mass production, by employing engineering methods and machines, that it only required capital and men to build these facilities. The government and the people supplied the money willingly, and it is one of these projects, for the manufacture of ammonia nitrate, that I will first describe.

*Of E. P. Heckel and Associates, Consultants.

Manufacture of Ammonia Nitrate

Ammonium nitrate enters as a constituent in the loading of high explosive shells, such as depth bombs, projectiles and mines. The particular method of manufacturing this product that I shall outline, was selected for the availability of the raw materials, and because of the exactness of controlling uniformity in mass production. The raw materials used were ammonium sulphate

A coast defense battery at target practice

Signal Corps U. S. Army

$(NH_4)_2SO_4$, sodium nitrate $NaNO_3$ and sodium carbonate Na_2CO_3, commonly known as soda ash.

Ammonium sulphate is a byproduct of the manufacture of illuminating gas, available in large quantities and of low monetary value. Sodium nitrate is found in natural fields in this country and in South America, and is commonly known as Chilean nitrate, because of large natural deposits in Chile. Sodium carbonate or soda ash is a commercial product in great abundance and low in cost.

In this process, ammonium nitrate is a product brought about by the chemical combination of ammonium sulphate and sodium nitrate. However, these two when brought together give an acid reaction. To counteract this acid reaction, and in order to lengthen the life of the machinery, soda ash is added to neutralize and make the reaction slightly alkaline.

The material was weighed separately in definite quantities and then mixed in large kettles, continuously agitated and heated. After thoroughly mixing, it was filtered through continuous filters. Here sodium sulphate was filtered out as a precipitate and the resultant filtered liquor collected in a dilution tank. A definite quantity of distilled water was then added and the resultant liquor pumped through pipe lines into the crystallizer building.

The liquor entering the crystallizer building was at about 170 F. It was then cooled to a temperature of 100 F by passing through a double pipe cooler, known as a precooler, using available water. This cooling was controlled thermostatically and the liquor left the precoolers at a constant temperature. After passing through the precoolers the liquor went to a constant level tank, from where it was pumped to the crystallizing rooms.

There were eight crystallizing rooms, each 36 ft wide by 128 ft long by 40 ft high and containing 15 tiers of metal pans, each tier being eight pans high, or a total of 120 pans per room (960 pans for eight rooms) to produce 600 tons of ammonium nitrate per 24 hr.

The liquor pumped from the constant level tank was distributed among the pans and allowed to remain in them until cooled to a temperature of 68 F. This cooling was of extreme importance, in order to assure pure ammonium nitrate crystals of proper formation and at the same time to prevent the formation of other undesirable crystals. The liquor in the pans contained two salts, ammonium nitrate and sodium nitrate.

In order to obtain pure ammonium nitrate crystals of proper form, it was necessary to avoid excessive surface cooling and to minimize surface evaporation. Due to the very narrow limits between the temperature at which ammonium nitrate crystallizes, and the other salt in the liquor begins to crystallize, it was imperative that cooling be accomplished by the air surrounding the pans rather than by any other method.

It was necessary to maintain a vapor pressure in the air surrounding the pans equivalent to or greater than the vapor pressure in the liquor at any given time while cooling. To maintain this vapor pressure in the air required maintaining a high relative humidity and a corresponding dew point.

As before stated the temperature of the liquor entering the pans was 100 F. Therefore, the highest vapor pressure in the liquor was approximately 1.05 in. of mercury, while the dew point necessary to establish an equivalent vapor pressure in the air was 81 F or a temperature difference of 19 F. The ideal crystallizing cycle therefore would then contemplate an initial dew point of 82 F in the air with a dew point constantly decreasing as the vapor pressure of the liquor decreases while cooling, so that the vapor pressure in the air could be always maintained slightly higher than the vapor pressure in the liquor. This prevents all evaporation and still effects rapid and efficient cooling.

Pure ammonium nitrate crystals were formed similar to the formation of stalagmites, while cooling the liquor to a final temperature of 68 F. The liquor remaining in the pans was then drawn off and mixed with mother liquor and was then ready to be pumped into the pans for formation of more crystals.

The crystals were shoveled out of the pans and dumped on conveyors which carried them to centrifuges. Here all remaining liquor was separated from the crystals. The crystals were then conveyed to a final storage house until ready to be shipped in ordinary box cars to shell loading plants.

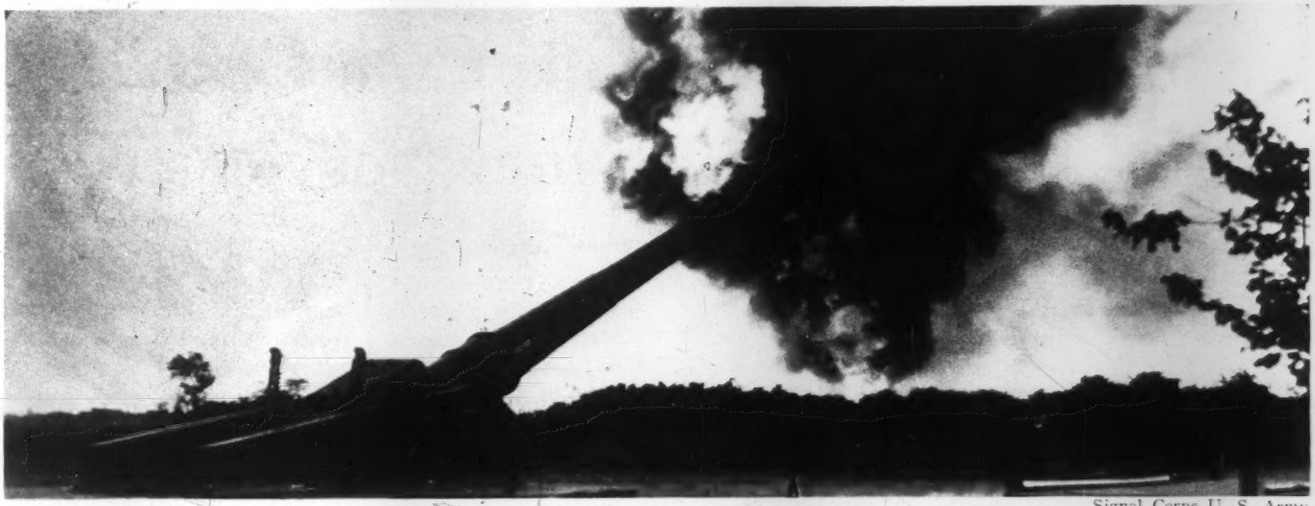
A few statistics on this plant, which was built in 1918, may be of interest. The project was started March 1, 1918. The plant was in two units or lines each of 300 tons capacity. The air conditioning equipment had a capacity of 300,000 cfm of air per unit, or a total of 600,000 cfm. The refrigeration plant had a capacity of 350 tons per unit or a total of 700 tons, corliss engine driven. It was necessary to build a steam power plant for the entire project for supplying steam and electricity for process purposes as well as for a complete new village, including a community building, stores, etc., for the employees, streets, lights, sewers, water facilities and of course all buildings and equipment for the manufacturing process.

The first unit, producing 300 tons daily, was in full production in July, 1918. On September 1 the second unit was placed in production. An additional project of equal size was ready to be started when word of the armistice was received. The two units cost $8,000,000.

Manufacture of Fuses and Star Shells

Another important application of air conditioning and refrigeration is for the manufacture of fuses for high explosive shells. There are two types of fuses, the percussion or direct impact which detonates by direct impact, and the time fuse. Time fuses also incorporate percussion so that in the event the time fuse fails to

Industrial process air conditioning plays an essential part in the manufacture of such ordnance as high explosive shells, depth bombs, mines, time fuses, star shells, etc. In time fuses, for instance, which are set before the shell leaves the gun to a predetermined time of bursting, the moisture content of the powder has a great effect on the burning time. As the moisture content depends upon the humidity conditions during manufacture, air conditioning is essential . . . Mr. Matzen explained this and other similar problems in ordnance manufacture before a recent meeting of the New York section of the American Society of Refrigerating Engineers, from which this article has been taken



Signal Corps U. S. Army

A 16 in. gun in action

function the shell can still be exploded by percussion. The discussion here will be confined to the time fuse.

A time fuse is a complicated unit attached to the nose of high explosive shells; it governs the time of bursting, predetermined before it leaves the gun from which it is shot. It is adjustable as to the interval of time between the point from where it leaves the gun to the point in the trajectory over the enemy line where it is desired to explode the shell.

A time fuse consists of a number of metal parts of brass or aluminum. These parts are precision machined and form what are known as the body, concussion plunger, primer, flash chamber, magazine charge, percussion element and usually two time trains containing powder, one upper and one lower.

The time trains are formed in rings loaded with fine black meal powder, compacted in place under high pressure—about 60,000 lb per sq in. in precision controlled presses. Any variation in powder compression interferes with a fixed desired burning time. Also, since the powder is extremely hygroscopic any variation in regain, *i.e.*, moisture content of the powder, has even a far greater effect on the burning time.

For mass production and uniformity it is necessary to control both temperature and relative humidity for the following reasons.

1) To assure precision work for the metal parts by maintaining a uniform temperature.

2) To maintain uniform moisture regain in the powder by maintaining a uniform relative humidity.

3) To avoid the generation of static electricity sparks by maintaining a sufficiently high relative humidity.

4) To avoid excessive perspiration of the workers to, in turn, avoid any possibility of adding moisture from their hands to the powder and materials, even though light cotton gloves are worn.

To meet these requirements a constant condition of 70 F dry bulb and a relative humidity of 50 per cent was found most suitable, and was maintained 24 hr per day.

The engineering problems involved in fuse loading plants present many unusual factors not ordinarily encountered in other manufacturing. Here we are constantly confronted with "made to order" explosion and fire hazards, the disastrous and full effect of which might readily result from any one of many causes, such as static spark, heat of friction, electrical sparks, and others.

To hold such possibilities to a minimum and to confine the effect or results of such occurrence, each loading room is made only large enough to accommodate one press, one or two workers, and raw materials. Many such rooms are necessary for large production and obviously must be individually air conditioned and individually equipped with automatic regulation to maintain the desired temperature and relative humidity. One thing of importance in the air distribution system is that the supply and return air ducts must be adequately equipped with both automatic and hand dampers, fire dampers, reliefs and explosion vents.

The air conditioning equipment should be of the water spray type and the refrigeration system a water cooling system, circulating the water to the various air conditioning units. Water systems are recommended so that any fine powder floating in the air may be collected in the spray apparatus.

Another product requiring air conditioning is star shells, which are manufactured of potassium and other chemical powders packed in a can equipped with a time fuse, and a number of small silk parachutes ranging in size from 2 in. to 18 in. in diameter. These were shot over the combat sector and after reaching a given height in their trajectory a very brilliant light was produced for a short period of time. For example, some would light for about three seconds and produce illumination equal to 300,000 candle power per second.

Potassium and other chemicals are very hygroscopic and highly inflammable. It was of course necessary to pack them under proper humidity conditions, corresponding to the desired regain. In fact, practically the same problems were presented as for fuse loading and the same conditions were found most suitable.

Another interesting application was the assembly of airplanes, which during the last world war were constructed almost wholly of wood. The wood parts were manufactured in many plants scattered over all parts of the country, under identical plans and specifications. It was soon found that, for mass production in assembling, and for safety of the plane, it was necessary to air condition the assembly plant to allow the wood parts to reach a definite uniform regain. This was necessary in order to obtain perfect fit and so that when the plane was assembled all parts would contract and expand equally when subjected to varying atmospheric conditions.

Attention to Details Cuts Cost of Heating and Other Services

By C. W. Kimball*

IN 40 years of experience with the design and operation of steam plants, we have never observed a better example of the value of attention to details than the results obtained at one of the larger hospitals in Boston.

In 1931 and 1932 new boilers, pumps and heaters were installed in this plant to replace worn out apparatus; steam flow, water flow and oil meters were also installed. With the money available, everything had to be kept as simple as possible. Therefore no special control system was installed and as much of the old apparatus was used as was possible.

This particular plant includes three 66 in. diameter 18 ft 0 in. HRT boilers brick set in battery and fired with No. 6 fuel oil through plain steam atomizing hand controlled burners which were transferred from the old plant to the new boilers. The boilers operate at 100 lb pressure and supply steam for the laundry, cooking, sterilizing, hot water and heating of the institution.

Shortly after the new plant was put in operation one of the trustees inaugurated a regular weekly inspection covering one building and its services each week. He also began to keep careful and detailed records of the fuel, steam, electric, water and laundry requirements and consumption. These records are carefully analyzed and compared to see that each branch of the service is functioning properly and economically and to determine what can be done to improve any part of the system. The weekly inspection of the buildings and equipment brings to attention all leaks, wasteful operation and needed repairs. Any irregularities or defects are noted and changes or repairs are attended to as promptly as possible.

These records now cover several years of operation and the results have clearly demonstrated their value; they set a standard that insures economical operation as long as the operating force continues to follow the methods developed.

As an illustration of the results obtained, the savings in the water bills now amount to over $3000 per year without curtailing any legitimate use of water. This saving was made possible by stopping all leaks promptly, saving water from condensers on the sterilizing equipment, changing two or three wasteful fixtures and purchasing all water on centralized meters.

In connection with the steam services, careful records are kept and thoroughly analyzed. Each month and year these records are compared with the preceding one with the result that everyone connected with the plant has taken an interest in trying to better the results and to raise the standards of comparison even higher. Although the hospital has cared for approximately one-third more patients per year, the fuel consumption has decreased.

In connection with the electric work, certain motors have been changed, a motor generator set has been eliminated, lamps changed and a continuous study has been made to save wherever possible.

The hot water service to the laundry has been improved and one or two new machines added.

The steam traps and the heating return system have been overhauled and each piece of apparatus is maintained in good condition so that excessively hot returns with their inevitable waste of vapor do not exist.

The steam mains have been rearranged to keep the operating pressure as low as possible and every building now heats thoroughly on 8 to 12 oz pressure.

The record now shows that the cost per patient day for heat, light, gas and water services has been reduced from approximately $0.70 to $0.50, and the service now given is better than before.

The hospital now has records that set certain standards for operation. Any deviation is sufficient cause for those in charge to ask "Why the change and what is being done to correct conditions?" The records are a guide for the engineer in charge and they serve to show whether any changes are right or wrong.

Too often in the past the steam plant has been considered a necessary evil, but this case shows that attention to all details, proper records and proper supervision will insure a worthwhile saving without excessive capital expenditures.

The records at this institution show that compared to previous costs the present methods have reduced the yearly cost of operation a net of over $10,000.

This seems to indicate that attention to details is well worthwhile.

*Of Richard D. Kimball Co., Engineers. Member of Board of Consulting and Contributing Editors.

Comparative Costs in Percentages of Total and Cents per Patient Day for a Hospital for Five Successive Years

Radiation Sq Ft	Patient Days	Fuel		Electric		Water		Labor		Supplies		Total Cost per Patient Day
		%	Pat. Day	%	Pat. Day	%	Pat. Day	%	Pat. Day	%	Pat. Day	
42,200	69,921	34.5	24.6	21.8	15.6	17.1	12.2	24.9	17.9	1.7	1.2	71.5c
42,200	68,112	35.8	24.8	20.0	13.8	17.8	12.3	25.5	17.7	0.9	0.6	69.2c
52,369	82,716	31.8	17.8	21.8	12.2	15.5	8.7	29.1	16.3	1.8	1.0	56.0c
52,369	86,803	32.8	17.6	23.9	12.8	14.3	7.7	26.6	14.3	2.4	1.3	53.7c
52,369	95,594	30.8	15.5	23.9	12.0	13.7	6.9	29.1	14.7	2.5	1.3	50.4c

Uniform Temperature and Humidity Protect Valuable Italian Exhibit

THE Art Institute of Chicago has taken every precaution to guard the Italian masterpieces of art on special exhibit there against any deterioration and to show them under ideal conditions. Including some of the most famous and best-loved works in the entire history of art—such as Raphael's Madonna of the Chair, Botticelli's Birth of Venus, Michelangelo's Madonna and Child with the Young St. John, to mention but three—the exhibit created a sensation when shown at the Golden Gate International Exposition. Ordinarily, one would have to travel from one end of Italy to the other to see these masterpieces of painting and sculpture, which are valued at $150,000,000.

According to James F. McCabe, the institute's superintendent of buildings and responsible for all exhibits once they have been placed on display, constant temperature and humidity conditions in the galleries are vitally necessary to the complete protection of the paintings. Changes in the wood of the frames and in the canvas occur with varying temperatures and humidities; if uniform atmospheric conditions are provided, checking of the wood and the paint is prevented. For this reason a temperature of 70 F and a relative humidity of 40 per cent are maintained constantly in the Italian exhibit galleries. A member of Mr. McCabe's staff spends the entire day from 9:00 a. m. to 10:30 p. m. taking temperatures and humidities (with a hand aspirated psychrometer) throughout the rooms, and adjusting valves in the steam lines to the radiators and humidifiers to keep them constant. The night crew continues the observations, which need not be made so often, of course, when there are no visitors.

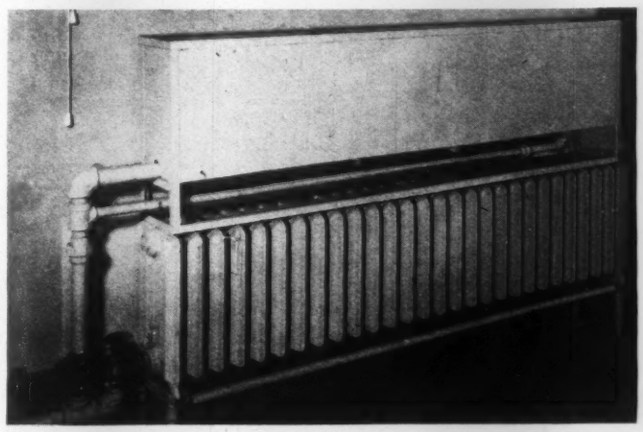
The institute does not have air conditioning equipment for controlling humidities in its galleries, except in a recently completed wing which is described briefly below. When it was found that the Italian masterpieces could be brought to Chicago, it became necessary to install equipment for humidifying the air. The problem was solved by using radiator vent valve humidifiers installed in series as shown in the illustrations. These valves, ordinarily installed in place of the air valve on a steam radiator, take steam from the line and release it to the room. Forty-eight of these valves, installed in two sets of 24 each, are used for humidifying the galleries where the Italian works are displayed. These galleries have a volume of 164,608 cu ft. Each valve is rated at a maximum capacity of 1½ to 2 pints pr hr at the pressure used.

Two radiators were installed in the ante-room area of the galleries. Over each is a sheet metal casing and in it is a steam line to which is attached 24 humidifier valves. The casing is lined with asbestos insulation to prevent condensation. A valve in the steam line allows manual control of humidification. Steam pressure at the radiators and humidifiers is maintained at about 2 lb or over. The steam line for the humidifiers is 1½ in. in diameter and was tapped at 5 in. intervals on each side. It runs along the top of the radiator and loops back into the supply line.

Depending on the temperature and humidity readings taken continuously throughout the galleries, the valves in the lines to the radiators and the humidifiers are adjusted by hand to keep the constant 70 F, 40 per cent relative humidity condition. Air is exhausted from the galleries to the attic space by a centrifugal fan in the attic space discharging through a 40 ft duct to the outside. This fan has several speeds, which allows the operator to vary the air circulation in the galleries and enables him to keep the condition in the galleries uniform. The air leaves the galleries around the edges of glass panels which form the ceiling; raising and lowering these panels—and the windows through which outside air enters—is another means of controlling the air circulation.

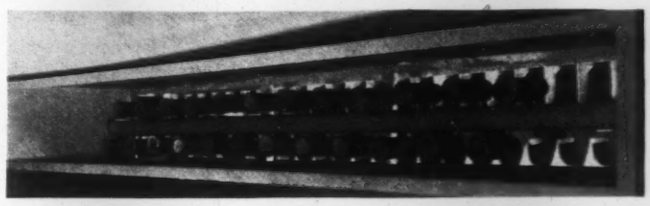
The 40 ft discharge air duct mentioned above runs across the attic space from the fan to the outside building wall, and is between the glass roof of the building and the glass ceiling of the galleries underneath. In order to avoid its throwing a shadow in the galleries, the bottom and top of the duct, which is 6 ft wide and 10 ft high, are made of glass. Its sides are sheet metal. By using this construction, no shadow is cast in the gallery below it and the duct is not noticeable from the gallery.

[*Concluded on p. 9*]



One of the two radiators and humidifiers installed by the Art Institute of Chicago for the Italian exhibit. The sheet metal casing, open at the top and bottom, encloses the 24 humidifiers

Looking down (obliquely) into the sheet metal casing, a side view of which is given in the other picture. The 24 humidifier valves may be seen, 12 on each side of the 1½ in. steam pipe line



The Psychrometric Chart

Its Application and Theory

By William Goodman*

IF air in the state represented by point *1* of Fig. 24 is mixed with air in the state represented by point *2*, the point representing the final state of the mixture will be a point such as *3* on a straight line connecting *1* and *2*. This is demonstrated in Appendix 5.

Air Mixtures

The exact location of point *3* depends upon the relative proportions of the air from the two sources present in the mixture. Obviously, if most of the air in the mixture was originally in state *1*, the resulting state *3* must lie closer to *1* than to *2*. The lengths of the segments L_1 and L_2 on the line *1-2* are inversely proportional to the weights of air present in the mixture. This is expressed by the following equation derived in Appendix 5:

$$\frac{L_1}{L_2} = \frac{G_2}{G_1} \qquad [17]$$

Point *3* of Fig. 24 can be located by direct measurement along line *1-2*. For example, if air in state *1* constitutes 75 per cent of the total air in the mixture, the distance L_2 must be 75 per cent of the total length of the line *1-2*. Another way of locating point *3* is to compute either the enthalpy or the absolute humidity of the mixture by means of one of the following equations:

$$h_3 = m_1 h_1 + m_2 h_2$$
$$w_3 = m_1 w_1 + m_2 w_2$$

where m_1 = fraction of the total air in the mixture that is drawn from source *1*;

m_2 = fraction of the total air in the mixture that is drawn from source *2*.

After computing either the enthalpy or the absolute humidity of the mixture, point *3* of Fig. 24 can be located where either the line of computed enthalpy or of absolute humidity intersects line *1-2*.

Occasionally, air from two sources may be in such a condition that the resulting mixture will lie to the left of the saturation curve—in other words, in the fogged field as shown in Fig. 25. A mixture of two streams of unsaturated air can produce fogged air. In such a case the final temperature of the saturated fogged air is read along the wet bulb line through point *3* of Fig. 25.

Fogged air can be cleared by mixing it with unsaturated warm air. This is illustrated in Fig. 26. Fogged air in condition *1* is mixed with sufficient unsaturated air in condition *2* so that the resulting state of the mixture lies at point *3*.

Symbols Used in Text

(For complete list of symbols, see p. 358, June, 1939 issue)

G = weight of dry air, lb per min
G' = weight of water, lb per min
h = enthalpy of air-vapor mixture, Btu per lb of dry air in the mixture
h_f = enthalpy of moisture in liquid state, Btu per lb of water
h_g = enthalpy of moisture in vapor state, Btu per lb of vapor
h_w = enthalpy of moisture in any state, Btu per lb of moisture
Q = quantity of heat added to the air or removed from it, Btu per min
t' = wet bulb temperature, deg Fahr
W_w = weight of moisture evaporated into the air or condensed from it, lb per min
w = absolute humidity of the air-vapor mixture, lb of moisture per lb of dry air in the mixture
θ = moisture ratio angle. See Table 1.

Subscript "1" refers to the initial state of the substance and subscript "2" refers to its final state.

If air from one of the two sources is below the freezing temperature, a mixture of saturated air and snow may be produced. This is illustrated in Fig. 27. Air from source *1* is mixed with air from source *2*. The resulting condition of the mixture is point *3*, which lies to the left of the saturation curve and below the temperature line for 32 deg. In such a case, snow will probably be formed. The slope of the wet bulb line through point *3* will correspond to the enthalpy of ice.

Interpretation of Ratio Lines

As is apparent from the discussion of the moisture ratio given in Part 3 in the August issue, the ratio line is only the path of all the possible points representing the *final* state of the air leaving a chamber that is supplied with a constant quantity of heat and moisture. The ratio line is not the path of the points representing the *actual* state of the air as it passes through the conditioning apparatus. The two paths do not always coincide. The ratio line should not be confused with the path that the air actually follows as it passes through the conditioning equipment.

In the conditioning process illustrated by Fig. 2 and discussed in Part 1 in the June issue, both heat and moisture are added to the air. If, as is frequently the case in conditioning apparatus, the heat is added first and the moisture last, the actual condition of the air as it passes through the heaters and water sprays will be

*The Trane Co. Member of Board of Consulting and Contributing Editors.

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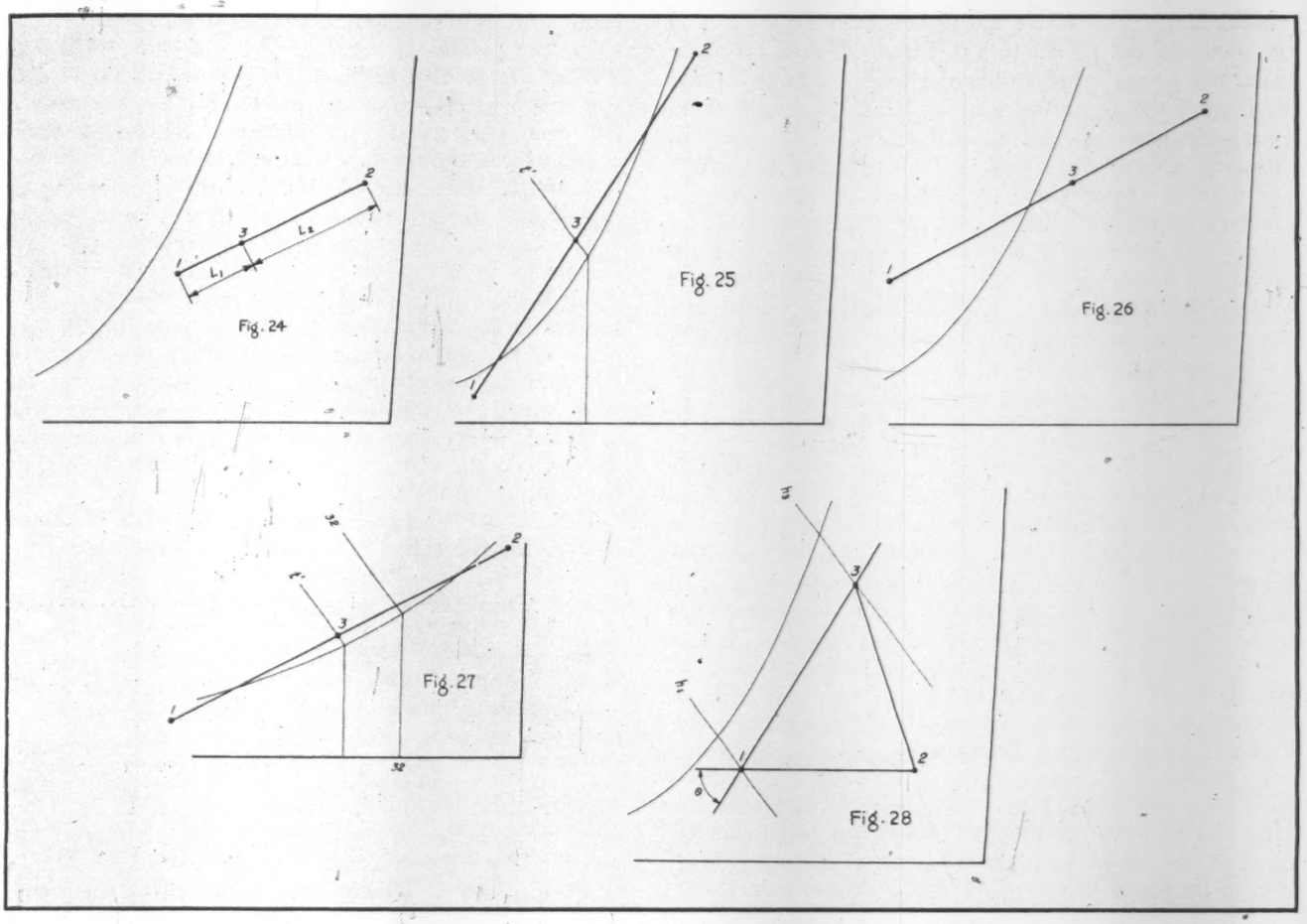


Fig. 24—Method of determining state of a mixture of air from two different sources. Points *1* and *2* represent the states of the two original streams of air. Point *3*, representing the state of the mixture, must lie on the straight line connecting points *1* and *2*. . . . Fig. 25—Illustration showing that fogged air can be obtained by mixing two streams of unsaturated air. . . .

Fig. 26—Method of clearing fogged air by mixing it with warmer, unsaturated air. . . . Fig. 27—A small amount of snow can be obtained by mixing two streams of unsaturated air. . . . Fig. 28—Illustration showing that the actual path *1-2-3* of the air flowing through the conditioning equipment does not necessarily coincide with the ratio line *1-3*. (Processes illustrated are explained in text)

represented by lines such as *1-2* and *2-3* of Fig. 28. Point *1* represents the initial condition of the air entering the apparatus. It is heated from point *1* to point *2* at constant absolute humidity. As the air passes through the sprays, the condition of the air changes along the ratio line *2-3*, the slope of which is determined by the initial enthalpy of the water. Assume for this case that point *3* represents the final condition of the air leaving the apparatus. Although the air actually follows the path *1-2-3* in passing through the conditioning chamber, the ratio line is *1-3*.

The point representing the final state of the air leaving the conditioning apparatus must lie somewhere on the line *1-3* if the quantities of heat and moisture added in the chamber are always constant. The actual total heat removed could be figured either from the change in enthalpy of the air between points *3* and *1*—that is, $(h_3 - h_1)$—or by measuring the ratio angle of the ratio line *1-3*. In the first case, the change would represent Btu per lb of dry air passing through the apparatus. In the second case, the moisture ratio corresponding to the measured ratio angle would give Btu per lb of water evaporated into the air.

There are a few special cases in which the actual path of the air as it travels through the conditioning apparatus coincides with the ratio lines. One of these cases, discussed previously, is an apparatus in which the air is not treated in any way except that either water or steam is sprayed into the air, and none of this water or condensed steam leaves through a drain pipe or recirculating pipe. Another case, discussed later, is that of a spray chamber in which the same water is continually recirculated. If the water is neither heated nor cooled as it is recirculated, the path of the points representing the change in the condition of the air as it flows through the spray chamber will coincide with the ratio line which, in this case, is also the line of constant wet bulb temperature. Aside from these few special cases, the line or lines formed by the points representing the actual condition of the air as it flows through the conditioning apparatus do not coincide with the ratio line.

Variable Moisture Ratios

In the earlier discussion of moisture ratio, the statement was made that all of the points representing the final condition of the air leaving a conditioning apparatus would fall on a straight line only if the right-hand member of equation 3 was constant. Equation 3 is:

$$\frac{h_2 - h_1}{w_2 - w_1} = \frac{Q}{W_a} + h_a$$

There are many cases that occur in the analysis of air

conditioning cycles where the right-hand member of this equation will not reduce to a constant. Hence, for these cases the points representing the final condition of the air leaving the apparatus will not fall on a straight line. One such case is illustrated in Fig. 29, which shows an ordinary coil used to cool and dehumidify air. The coil may be cooled either by a direct expansion refrigerant or by chilled water. In either case, a quantity of heat, Q, is removed from the apparatus. The moisture condensed from the air, and which leaves through the drain pipe, is represented by the quantity, W_o. Writing the energy equation for this case as heretofore, the following equation results:

$$\frac{h_2 - h_1}{w_2 - w_1} = \frac{Q}{W_o} + h_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [18]$$

This equation is the same in appearance as equation 3. However, the resemblance is only superficial because there is a fundamental difference in the two cases for which these equations were derived. In the case discussed for Fig. 2, the right-hand member of equation 3 reduces to a constant, because it was stipulated in the text in which Fig. 2 was discussed that the process was one in which the quantities of heat and moisture added to the air were constant. In other words, some type of control was provided or the conditions under which the heat and moisture were added were such that the quantities of heat and moisture added to the air were constant. Of course, in such a case, for different final states of the air leaving the chamber, the weight of air flowing through the chamber must change; equation 1 must always be satisfied.

Because of the conditions for which equation 3 was written, all of the quantities in the right-hand member of equation 3 remain constant; they do not change regardless of any change in the value of h_2 and w_2. In equation 18, on the other hand, the value of Q representing the quantity of heat removed by the coil must change as h_2, the final enthalpy of the air, changes. In addition, the value of W_o will also change as the value of w_2 changes. The lower the final absolute humidity of the air, the greater will be the quantity of condensate that leaves through the drain pipe of the apparatus. Consequently, for the process illustrated in Fig. 29, the right-hand member of equation 18 is not a constant. Hence, all of the points representing the final state of the air leaving the cooling coil will not lie on a straight line. For a coil used to cool and dehumidify air, the ratio of the heat removed to the moisture condensed varies constantly as the air flows through the coil.

Another process for which the points representing the final state will not lie on a straight line is an air washer in which water leaves through a recirculating pipe, and the water is either heated or cooled as it circulates through the piping outside of the spray chamber. This process is illustrated in Fig. 30. Assume for the purposes of this discussion that cold water is supplied to cool and dehumidify the air. The discussion that follows would be equally valid if the assumption were made that warm water was supplied to heat and humidify the air. As the water cools and dehumidifies the air, the temperature of the water increases.

Writing the energy equation for the case illustrated in Fig. 30, and solving for the moisture ratio,

$$\frac{h_2 - h_1}{w_2 - w_1} = \frac{G'}{W_o}(h_{t2} - h_{t1}) + h_{t2} \quad \ldots\ldots\ldots\ldots [19]$$

The heat absorbed by the water is

$$Q = G'(h_{t2} - h_{t1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [20]$$

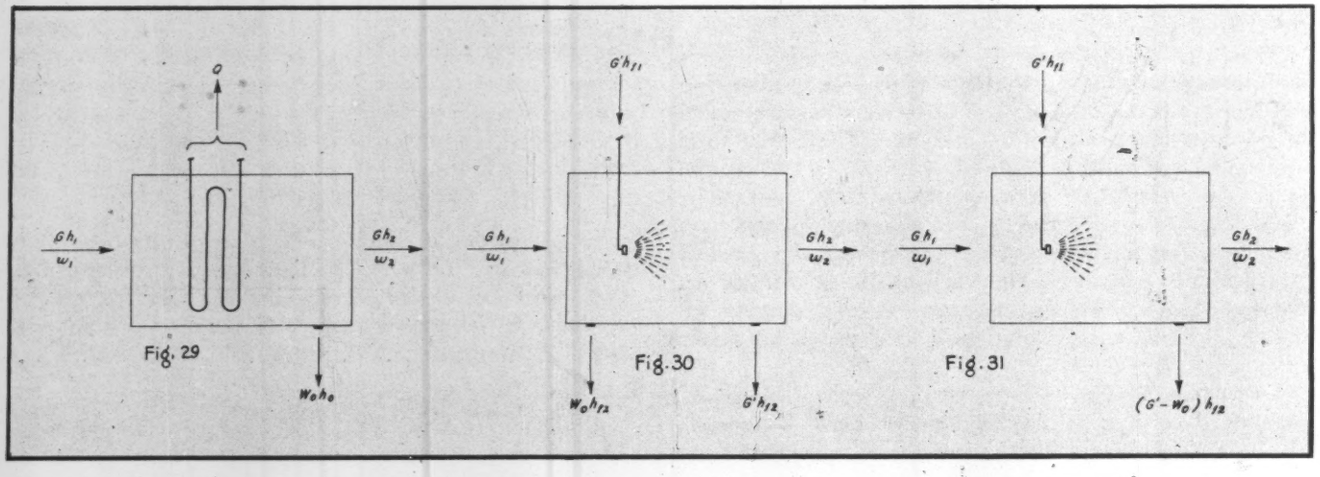
Substituting this into equation 19,

$$\frac{h_2 - h_1}{w_2 - w_1} = \frac{Q}{W_o} + h_{t2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [21]$$

Here also, equation 21 resembles equation 3. However, it is readily apparent that Q, the quantity of heat absorbed by the water, will vary as h_2, the final enthalpy of the air, varies. The lower the value of h_2, the greater must be the value of Q, the heat absorbed from the air by the water. This is also apparent by inspection of equation 20. As h_{t2}, the final enthalpy of the water and hence the final temperature of the water, increases, the value of h_2, the final enthalpy of the air, will decrease. Inasmuch as the right-hand member of equation 21 is not constant, the points representing the final condition of the air leaving the washer cannot lie on a straight line on the psychrometric chart.

Another common case encountered in which the moisture ratio will not reduce to a constant is the familiar type of humidifier in which warm water is sup-

Fig. 29—Diagrammatic illustration of coil used for cooling and dehumidifying air. . . . Fig. 30—Diagrammatic illustration of an air washer in which water is continually recirculated and cooled outside of the washer. . . . Fig. 31—Diagrammatic illustration of spray nozzle used for humidifying air in which the excess water is wasted through a drain pipe. (Processes explained in the text)



plied to a nozzle and the excess water which does not evaporate is wasted through a drain pipe. This case is illustrated in Fig. 31. Writing the energy equation for the case illustrated in Fig. 31 and solving for the moisture ratio,

$$\frac{h_2 - h_1}{w_2 - w_1} = \frac{G'_1}{W_o}(h_{f1} - h_{f2}) + h_{f2} \quad \ldots\ldots\ldots\ldots [22]$$

Here also, the right-hand member of equation 22 does not reduce to a constant because as the quantity $(h_2 - h_1)$ increases, the quantity $(h_{f1} - h_{f2})$ must also increase because the heat gained by the air is equal to the heat surrendered by the water.

If none of the water supplied is wasted through the drain and all of it is evaporated, then (G'_1/W_o) is equal to one and equation 22 reduces to

$$\frac{h_2 - h_1}{w_2 - w_1} = h_{f1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [23]$$

For the condition that $G'_1/W_o = 1$, the humidifying process illustrated in Fig. 31 will be represented by a straight line on the psychrometric chart. Where some of the water supplied is wasted through the drain, a straight line whose enthalpy corresponds to the initial water temperature may be used to represent the process approximately if the value of (G'_1/W_o) is close to one.

From the discussion in the preceding paragraphs of this section, it is apparent that any case analyzed in air conditioning must be carefully scrutinized to determine whether or not the right-hand member of equation 3 reduces to a constant.

For the special case in which all of the spray water is either evaporated into the air or entrained by it, the points representing the final condition of the air will lie on a straight line. This is also true for the case in which steam is sprayed into the air, providing that if any of the steam is condensed, the condensate is entrained by the air stream and carried away with it. For these cases, the final condition of the air leaving the apparatus will lie on a straight line.

There is one special case of an air washer in which return water leaves through a recirculating pipe for which all of the points representing the final state of the air will fall on a straight line. This case is the familiar air washer in which the water is neither heated nor cooled as it is recirculated. Inasmuch as the water is neither heated nor cooled, the final temperature of the water leaving the washer is the same as the initial temperature of the water entering it. Hence, for this equation the value of Q reduces to zero as is evident from equation 20. Therefore, if Q is zero, equation 21 reduces to

$$\frac{h_2 - h_1}{w_2 - w_1} = h_{f2} = h_{f1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [24]$$

That is, the moisture ratio is constant and equal to the enthalpy of the water which is being circulated at constant temperature. The constant temperature which the circulating water will assume is equal to the wet bulb temperature of the air. Therefore, for this case also, the final condition of the air leaving the washer will be represented by a point which lies on a straight line of constant wet bulb temperature. Although this fact is well known, the manner in which it is derived as a special case of a more general proposition is nevertheless of interest.

[*To be continued*]

The solution of air conditioning problems involving mixtures of air by means of psychrometric charts, and the interpretation of moisture ratio lines, are explained this month. Another topic covered is that of air conditioning processes where the points on the chart representing the final condition of the air leaving the conditioning apparatus do not fall on a straight line on the chart. Typical cases of air conditioning processes of this kind are presented and discussed. . . . Psychrometric charts are fundamental tools of engineers engaged in comfort and process air conditioning work, including drying. The series of which this article is a part includes new charts for the low, medium and high temperature ranges, a discussion of the theory underlying them, and an explanation of how the various types of problems may be solved

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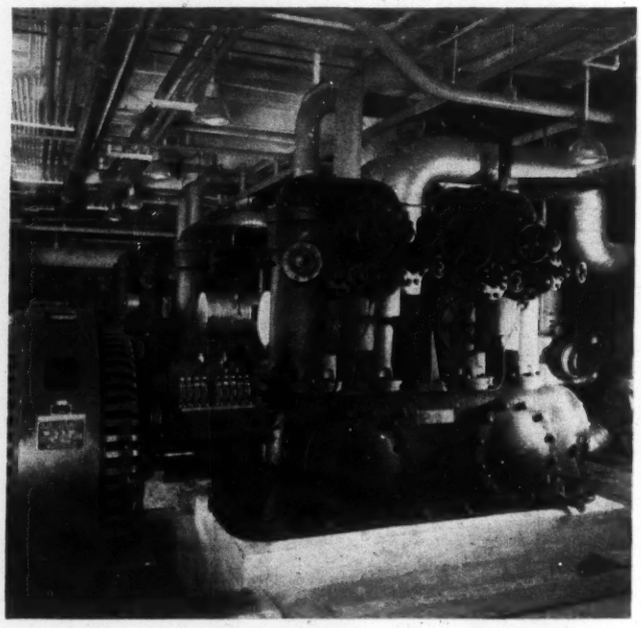
[*Concluded from p. 5*]

In addition to the control of temperature and humidity, the paintings and sculpture were carefully lighted. Various types of spot and other lights, situated in the attic space and throwing light through the glass ceiling panels or through apertures in the ceiling, are used. For the Madonna of the Chair, as an example, a stereopticon light illuminates the picture itself, and smaller lights are thrown on the gold frame. For the sculpture, lights were arranged to cast the proper shadows to show the modeling and the chisel marks.

In the institute's new wing, which was just recently opened, the galleries are winter air conditioned. Because it may be desired to hang pictures or other objects any place on a gallery wall, there are no grilles or thermostats on any of the walls in these new galleries. The heated and humidified air is introduced through specially designed combination ceiling lighting and grille units. Air is exhausted through grilles situated in the reveals of the arches between the different rooms, and the control thermostats are in the return air stream immediately behind these grilles. All of the heating in the new portion is done indirectly, there being no direct radiation installed. Thus, no wall space whatever is taken up by equipment.

Raphael's Madonna of the Chair

DU PONT SPENDS A MILLION FOR AIR CONDITIONING

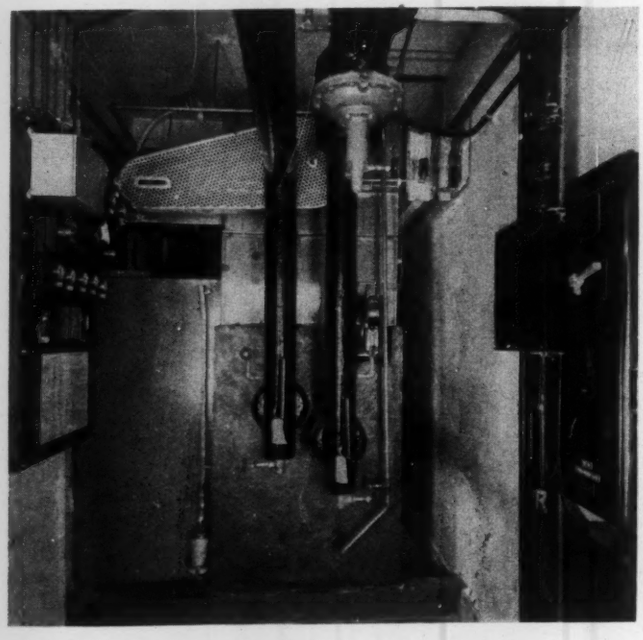


Engineers of E. I. du Pont de Nemours & Co. recently completed installation of a million dollar air conditioning system in the company's headquarters building, Wilmington, Dela. The block square, 13 story building encloses a large court and two supplementary light wells, has 1480 offices accommodating 4000 persons. Total rentable office area is 450,721 sq ft. The ground floor and a section occupied as a hotel were not included in the air conditioning. The equipment costs made up 79 per cent of the total for air conditioning, and dismantling and moving cost about five per cent. Alterations and additions to the building accounted for 16 per cent of the expenditure. The estimated operating cost is approximately 1½ per cent of the salary roll

Refrigerating equipment of 1200 tons capacity is in the basement, with cooling tower on the roof. Pipes and mains were carried in pipe chases where possible; in some instances they were run through offices under false ceilings and placed in the court outside. The equipment is all controlled from a central control panel which includes switches for fans and pumps in each section, the cooling tower fans, excitation switches for motors and similar controls. The entire system can be cut on or off at this board. An automatic recorder is installed to record various temperatures, and two flow meters record the volume of the condensing water and the chilled water circulated

Capacity of the system is 358,740 cfm of air circulated through 5.3 miles of ducts from 42 conditioning units to which chilled water from the refrigeration plant is piped. One of the units is shown here. Horizontal ducts are carried along corridors, concealed by special metal hung false ceilings. All rooms except those at corners tap the flow direct from the corridor duct; at corners, offsets from the central line were necessary. Recirculation is accomplished by grilles in the doors, the air passing free through corridors back to the conditioner rooms

Prefabricated false ceilings of unperforated acoustic pans cover the ducts along 11,950 ft of corridors. The pan units are removable, permitting ready access, as shown here. Existing ceiling heights varied widely. In a number of instances it became necessary to carry the duct in the room side of the partitions, then fur and plaster the setback. Office lighting fixture changes were required in many cases where the offset interfered with illumination. A new corridor lighting system was installed with shallow fixtures designed to give a maximum light spread



Proposed American Standard for Butt Welding Fittings Submitted

By Sabin Crocker*

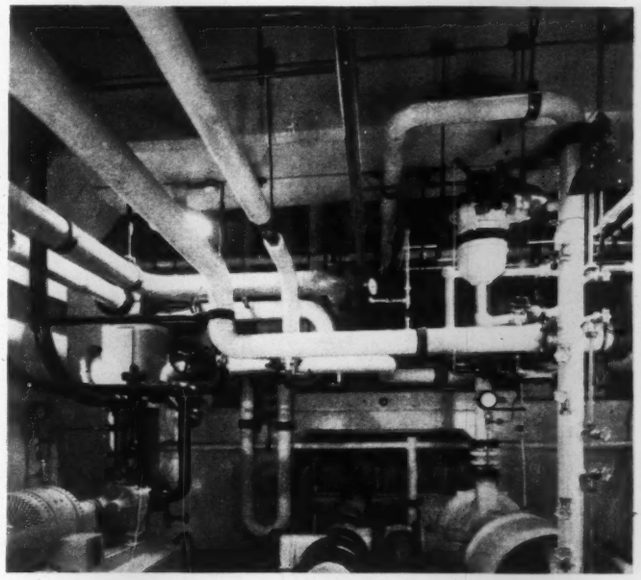
IN the light of today's acceptance of fusion welding the fact is often overlooked that this art was comparatively undeveloped and was used only to a very limited extent less than 10 years ago. Fusion welded boiler drums were not countenanced by the ASME boiler code committee until 1931, and up to that time the implied distrust of welding tended to dampen the enthusiasm of those who otherwise might have tried welding the high pressure joints in their power piping systems. The comparatively recent acceptance of welded construction by the boiler code committee has been predicated primarily on the demonstrated ability of welding operators to produce sound welds during qualification tests plus, for severe service conditions, certain additional requirements as to stress relief and non-destructive examination of the weld metal for flaws.

Also it was about this time that engineers began to sense the effect of chemical composition on the weldability of steel, as well as to appreciate the advantages of coated electrodes and multipass work for arc welding and of the reducing flame for gas welding. None of these contingent advances in knowledge of the art of welding, which gave so sudden an impetus to its universal acceptance, were given much thought until about 1930. Hence it is only within the present decade that fusion welded pipe joints have come into sufficient use to arouse interest in the formulation of safety codes governing the quality of welding and details of attachment, or in writing specifications defining the composition of metals suitable for welding, or finally in setting up standards for the overall dimensions of ready made welding fittings. It is with the last named that this article is directly concerned.

Delay in Standardizing

As often happens, there is no particular incentive for setting up a standard until industry has built up a demand for the product in question and various sources of supply start offering equivalent articles of varying dimensions. Standardization then enters the picture in an effort to resolve the discordant product into a single common denominator. This delay before attempting to standardize not only postpones deriving the benefits thereof, but often results in several manufacturers having to alter their shop equipment in order to make their respective products conform.

While this deliberate procedure seems wasteful in one sense, nevertheless it is preferable to impeding progress through prematurely stifling those impulses to invent or originate which contribute so much to real progress.



Low pressure piping around main condenser hot well at the Delray power plant showing schedule 40 pipe and welding fittings

Perhaps this explains why an American Standard for ready made *butt* welding fittings is only just now evolving through the procedure of the American Standards Association whereas the first brand of this product appeared on the market some 10 years ago. A proposed standard for *socket* welding fittings will be a year or so later in putting in its appearance owing to the commercial situation now existing with respect to this type of fitting. Sometimes, before a consensus can be reached, it is necessary to take time for trial in service or for learning how the consuming public responds to

A discussion of the new Proposed American Standard for Butt Welding Fittings is presented here—together with the standard itself—by the chairman of the subgroup which was responsible for its development. In describing the background of the standard, the author takes the opportunity to comment upon the development of welding during the past decade, and the general problem of standardization work in the piping industry. . . . HEATING, PIPING AND AIR CONDITIONING has always devoted major editorial attention to standardization work in the piping and other fields, for the subject is of importance to all. Presentation of this new standard supplements, therefore, the previous information on standardization in these pages

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the appeal of different designs as an indication of which should be adopted as standard. Then, too, it may take time for the manufacturers to work out between themselves a mutually acceptable set of compromise dimensions which do not place all the burden of conforming on one or two manufacturers to the advantage of others whose dimensions happen to suit. This situation is manifest in the case of *socket* welding fittings, but there is promise that divergent viewpoints can be reconciled within the next few months.

The subgroup also has considered standardization of the related product, backing strips, for use in making welded joints. It was the subgroup's finding that practice differed so greatly between different users, and design changes were being made so rapidly, that it was neither feasible nor desirable to standardize on backing strips at present. When practice has become somewhat more uniform, further consideration may be accorded the matter by the subgroup. The subgroup has under consideration standardization of dimensions for laterals, reducing tees, etc., agreement on which, however, has not yet been effected.

Conflicting Dimensions

About three years ago some of the users of butt welding fittings became aware of the need for standardizing this product. Aside from having in use three sets of center-to-end dimensions for elbows embracing short, medium and long radius with variations in each series depending on the manufacturer, there were two radically different styles of branch outlets for tees, and numerous inconsistencies in the dimensions of tees on the run and of reducers, caps and the like. Owing to this situation it behooved the user of welding fittings to select one manufacturer and stick to his line of fittings in order to avoid conflict of dimensions in making detail drawings or in field erection. If the fittings of another manufacturer were purchased inadvertently and mixed with those intended for the job, the pipe line as actually erected in the field was apt to be several inches too long or too short, or to have branch outlets unexpectedly misplaced as a result of variation in overall dimensions of welding fittings.

This situation was equally bad for both manufacturers and consumers since if a consumer had to confine his purchases to one brand for uniformity, this tended to exclude other manufacturers from competing for the business. Consequently, when the need for standardization was broached to the manufacturers they agreed wholeheartedly and, after more than two years intensive work, a first and very important section of the standard is now being balloted on by ASA sectional committee B16 following unanimous adoption by its subgroup No. 6 on welding fittings. The present section, which covers overall dimensions, tolerances and marking for the more common butt welding fittings, is reproduced here.

Scope of Standard

Examination of this standard will disclose that it embraces overall dimensions, tolerances and marking for 45 and 90 deg elbows, 180 deg return bends, concentric and eccentric reducers, caps, and lapped-joint stub ends. Dimensions of tees are given on the run only, because agreement among manufacturers has not been reached as yet on the branch dimension of either full size branch outlet tees or those reducing on the branch. As a practical compromise the center-to-end dimension of 90 deg elbows was made approximately 1½ times the nominal diameter, with 45 deg elbows and return bends shaped to agree.

Since standard dimensions for welding neck flanges already published in ASA B16e-1939 cover a considerable number of pages it was not deemed expedient to reproduce them with the welding fitting standard. It might be well to point out also that, since the present proposed standard is limited to what are aptly described as ready made or factory made fittings, there is no occasion for it to embrace rules for the reinforcement of welded branch connections fabricated in field or shop or for other built-up fittings the construction of which can better be left to the rules of the American Standard Code for Pressure Piping.

With respect to metal thickness at the welding ends, the standard mentions that since the dimensions of the welding bevel are to match pipe they must conform with established pipe standards. Hence dimensions at the welding ends are specified to comply with the schedule number system of ASA B36.10 on such sizes as are available, and those wall thickness schedules are included for reference. This practice of designating standard wall thickness is intended to supplant the use of "standard weight," "extra strong," and "double extra strong," which is fast becoming obsolete. Fittings are required to be equal in bursting strength to pipe of the designated schedule number and material.

Routine hydrostatic testing of fittings is not required (except of those made by casting) unless specifically called for in the order, but to meet code requirements and to provide for demonstrating the strength of design it is provided, however, that fittings *shall be capable* of withstanding a hydrostatic test made according to rules prescribed therefor.

Included in the standard is a recommended practice for the beveling of welding ends which also appears in connection with welding neck flanges in a recent edition of the American Standard for Steel Pipe Flanges and Flanged Fittings, ASA B16e-1939. Two cuts (see Figs. 1 and 2) are given to illustrate the respective bevels for wall thicknesses of $\frac{3}{16}$ to ¾ in., inclusive, and for thicknesses greater than ¾ in. Owing to a prevalent misconception as to what constitutes recommended practice for welding bevels, particular attention is directed to these details.

The recommended practice contemplates a 37½ deg beveled end for wall thicknesses from $\frac{3}{16}$ to ¾ in. inclusive rather than the 45 deg bevel previously common with the trade. The 37½ deg bevel does not require depositing quite so much weld metal and at the same time brings the detail into agreement with the practice of the American Petroleum Institute for line pipe, an extensively used product.

Materials Specification

Concurrently with sectional committee B16's work on the dimensional standard, a subcommittee of the

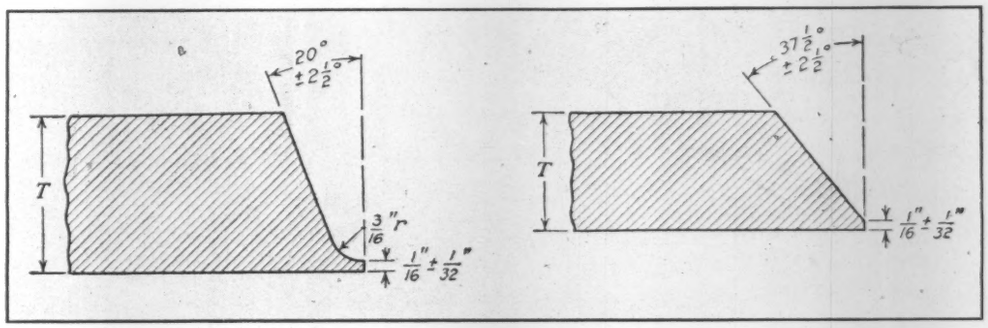


Fig. 1 (*right*) — Standard straight bevel of welding ends for thickness (T) $\frac{3}{8}$ to $\frac{3}{4}$ in., inclusive . . . . . Fig. 2 (*left*)—Standard U-bevel of welding ends for wall thickness (T) greater than $\frac{3}{4}$ in.

American Society for Testing Materials has been formulating a materials specification for welding fittings. This specification is predicated on the existence of numerous ASTM specifications for steel pipe, forged or cast fittings, and plate, which specifications also are suitable for ordering the material used in the manufacture of ready made welding fittings. Hence the idea of the ASTM subcommittee has been to draft a master specification for welding fittings which will incorporate all appropriate ASTM specifications through cross reference and furnish such further requirements as may be needed to provide for heat treatment and testing of the finished product. Such a master specification for carbon steel welding fittings is well along and should be published within the year. Probably a separate specification set up along similar lines will be required for fittings made of the various alloy steels if and when alloy welding fittings are used in sufficient quantities to justify a national specification.

Acceptance by Industry

A previous (November, 1938) draft of the dimensional standard for butt welding fittings was submitted for comment to the members of sectional committee B16 and to about 100 firms representative of industry or concerned with the manufacture or use of the product. A considerable number of letters of comment received as a result of this inquiry were considered by subgroup No. 6 at a meeting held in May, 1939, and many of the suggestions were approved and incorporated in the present draft. While it is obviously impossible to reconcile all opposing views within one standard, members of the subgroup feel that conflicting ideas have been sufficiently well harmonized to permit almost universal acceptance of the standard in its present form. For the accommodation of those who still want something different, the proposed standard provides that, "It is recognized that special fittings other than those specifically covered by this standard are available and may be ordered as required by the purchaser." As far as is known, the manufacturers of welding fittings have been 100 per cent represented on the working committees which formulated this dimensional standard and they have been unanimous in agreeing to conform. In some cases this has entailed a considerable sacrifice in scrapping existing tool equipment or in superseding or relegating to a special classification certain lines of nationally advertised fittings. The manufacturers of this product are to be commended for the cooperative spirit of give and take manifest by them throughout the whole undertaking.

Following the approval of sectional committee B16 by letter ballot vote this proposed standard will go to the three sponsor organizations, viz., the Manufacturers Standardization Society of the Valve and Fittings Industry, the Heating, Piping and Air Conditioning Contractors National Association, and the American Society of Mechanical Engineers for approval and transmission to the American Standards Association.

Proposed American Standard Butt Welding Fittings

Introductory Notes

1 Scope. This standard covers overall dimensions, tolerances, and marking for welding fittings which shall be known as American Standard Butt Welding Fittings. It is recognized that special fittings other than those specifically covered by this Standard are available and may be specified as required by the purchaser.

2 Pressure Ratings. Fittings shall have pressure and temperature ratings based on stresses permitted under the Code for Pressure Piping (ASA B31.1) for the corresponding material.

3 Size. The "size" of the fittings in the following tables is identified by the corresponding "nominal pipe size." For fittings 14 in. and larger the corresponding OD of the pipe is given.

4 Marking. Identification marks, consisting of a manufacturer's name or trademark, the schedule number, the material, and the size shall be stamped, stenciled or otherwise suitably labeled on each fitting, but when size does not permit complete marking, identification marks may be omitted in the order specified in the Standard Marking System for Valves, Fittings, Flanges, and Unions (MSS Standard Practice, SP25). Carbon steel fittings shall be marked with the symbol A or B where the basic material has chemical and physical properties conforming to Grade A or B pipe of ASTM Specifications for Lap Welded and Seamless Steel Pipe for High Temperature Service (A 106) (ASA B36.3), except that for schedule 40 Grade A low carbon steel, the schedule number and material markings may be omitted. Carbon-molybdenum steel fittings and all alloy fittings shall be marked with the symbols P1, P3, F1, etc., as established in the ASTM specifications for alloy steels for high temperature service.

On all alloy fittings, the manufacturer's name or trademark and the material specification shall be marked with a steel stamp[1] so that the markings will be of a permanent nature. The other markings may be stenciled or otherwise suitably labeled.

5 Material. The fittings covered by this Standard shall be made of pipe, tubing, plate, forgings or castings, and shall conform to the minimum requirements of ASTM specifications covering these materials.

[1]Where steel stamps are used, care should be taken so that the marking is not deep enough to cause cracks or to reduce the wall thickness of the fitting below the minimum allowed.

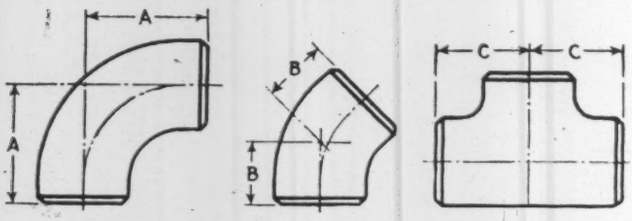


Table 1—Dimensions of Butt Welding Elbows and Tees[1]

Nominal Pipe Size	Outside Diameter at Bevel	Center-to-End		
		90 Deg Welding Elbows A	45 Deg Welding Elbows B	Of Run, Welding Tee[2] C
1	1.315	1½	⅞	1½
1¼	1.660	1¾	1	1⅝
1½	1.900	2¼	1⅛	2¼
2	2.375	3	1¾	2½
2½	2.875	3¾	1¾	3
3	3.500	4½	2	3½
3½	4.000	5¼	2¼	3¾
4	4.500	6	2½	4⅜
5	5.563	7½	3½	4⅞
6	6.625	9	3¾	5⅜
8	8.625	12	5	7
10	10.750	15	6¼	8½
12	12.750	18	7½	10

All dimensions given in inches.
[1]The dimensions of welding tees cover those which have branch outlets from one size less than half the size of the runway opening of the tees to full size.
[2]Dimensions from center to end of branch outlet have not been standardized as yet. See Par. 7.

6 Metal Thickness. As these fittings are to match pipe their strength and the dimensions at the welding ends must conform with established pipe standards. Nominal end dimensions other than for castings shall comply with the ASA pipe schedules as given in B36.10 (see Appendix) on such sizes as are available.

The actual bursting strength of fittings shall equal the computed bursting strength of pipe of the designated schedule number and material. To determine the relative strength of the fitting, straight pipe of the designated wall thickness and material shall be welded to each end, at least equal in length to the outside diameter of the pipe and with proper end closures applied beyond the minimum length of straight pipe, and hydrostatic pressure shall be applied until either the fitting or one of the short ends of pipe bursts.

The computed bursting strength of pipe shall be determined on the basis of the following formula

$$P = \frac{2St}{D}$$

where P = bursting pressure of pipe, lb per sq in.
S = minimum specified tensile strength of the pipe material, lb per sq in.
t = nominal pipe wall thickness, inches, according to schedule numbers in ASA B36.10 (See Appendix)
D = outside diameter of pipe, inches (See Appendix)

Since the above formula is applicable only to straight pipe it cannot be used for a direct computation of the bursting strength of fittings. Their ability to withstand bursting shall be gaged only by comparing their behavior on test with the calculated bursting strength of straight pipe of the designated wall thickness and material.

7 Fitting Dimensions. One of the principles of this standard is the maintenance of a fixed position for the welding ends with reference to the center line of the fitting or the overall dimensions as the case may be. Dimensions for elbows are established up to and including 12 in. Tees have established center-to-end dimensions of run only for sizes up to and including 12 in.; the center-to-end of branch outlets cannot be established, due to present practice not being in agreement and the processes employed limiting these dimensions to the differences now obtained. Dimensions for the 45 deg elbows and reducers are established up to and including 12 in., and for caps and lapped-joint stub ends up to and including the 24 in. size.

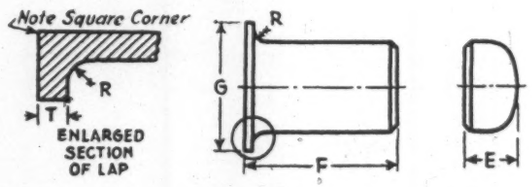


Table 2—Dimensions of Butt Welding Caps and Lapped-Joint Stub Ends

Nominal Pipe Size	Outside Diameter at Bevel	Welding Caps[1,2]	Lapped-Joint Stub Ends		
		E	Length[2] F	Radius of Fillet[3] R	Diameter of Lap[4] G
1	1.315	1½	4	⅛	2
1¼	1.660	1½	4	3/16	2½
1½	1.900	1½	4	¼	2¾
2	2.375	1½	6	5/16	3⅜
2½	2.875	1½	6	5/16	4⅛
3	3.500	2	6	⅜	5
3½	4.000	2½	6	⅜	5½
4	4.500	2½	6	7/16	6⅛
5	5.563	3	8	7/16	7⅝
6	6.625	3½	8	½	8½
8	8.625	4	8	½	10⅝
10	10.750	5	10	½	12¾
12	12.750	6	10	½	15
14	14.000	6½	12	½	16¾
16	16.000	7	12	½	18½
18	18.000	8	12	½	21
20	20.000	9	12	½	23
24	24.000	10½	12	½	27¼

All dimensions given in inches.
The basic minimum lap thickness (T) shall not be less than nominal pipe wall thickness.
[1]The shape of these caps shall be ellipsoidal and shall conform to the shape requirements as given in the ASME Boiler Construction Code.
[2]Dimensions "E" and "F" are applicable only to these fittings in schedules up to and including Schedule 80.
[3]These dimensions conform to the radius established for lap joint flanges in American Standard for Steel Pipe Flanges and Flanged Fittings (ASA B-16e—1939).
[4]This dimension is for standard facings in accordance with American Standard for Steel Pipe Flanges and Flanged Fittings (ASA B-16e—1939). Where ring joint facings are to be applied use dimension "K" as given in ASA B16e.

8 Tests. Welding fittings shall be capable of withstanding a hydrostatic test determined by the formula

$$P = \frac{2St}{D}$$

where P = maximum hydrostatic test pressure, lb per sq in.
S = 0.50 times the minimum specified yield point of the designated material, lb per sq in.
t = nominal wall thickness, inches, of designated schedule number of ASA B36.10 (See Appendix)
D = outside diameter at bevel, inches (See Tables 1 to 4 inclusive)

Hydrostatic testing of these fittings is not required in the Standard except those made by casting.

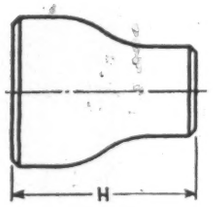
9 Tolerance.[2]

(1) Thickness of Shell. The thickness of shell at any point shall not be less than 87½ per cent of the nominal thickness (See Appendix)

(2) Outside Diameter of Fitting. Outside diameter of cylindrical portion of fitting adjacent to the welding zone

For sizes up to and including 2½ in.	+ 1/16 in.–1/32 in.
For sizes 3 to 4 in.	+ 1/16 in.–1/16 in.
For sizes 5 to 8 in.	+ 3/32 in.–1/16 in.
For sizes 10 to 18 in.	+ 5/32 in.–⅛ in.
For sizes 20 in. and larger	+ ¼ in.–3/16 in.

[2]These tolerances are based on the nominal dimensions given in the tables. Where tolerances closer than the above are required they are to be considered special and the maximum and minimum tolerance should be specified.



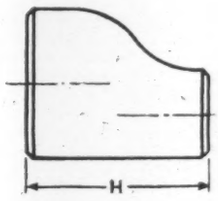


Table 3—Dimensions of Butt Welding Reducers

Nominal Pipe Size	Outside Diameter at Bevel, Large End	Outside Diameter at Bevel, Small End	End-to-End H	Nominal Pipe Size	Outside Diameter at Bevel, Large End	Outside Diameter at Bevel, Small End	End-to-End H
1 x ¾	1.315	1.050	2	4 x 3½	4.500	4.000	4
1 x ½	1.315	0.840	2	4 x 3	4.500	3.500	4
1 x ⅜	1.315	0.675	2	4 x 2½	4.500	2.875	4
				4 x 2	4.500	2.375	4
1¼ x 1	1.660	1.315	2	4 x 1½	4.500	1.900	4
1¼ x ¾	1.660	1.050	2				
1¼ x ½	1.660	0.840	2	5 x 4	5.563	4.500	5
				5 x 3½	5.563	4.000	5
1½ x 1¼	1.900	1.660	2½	5 x 3	5.563	3.500	5
1½ x 1	1.900	1.315	2½	5 x 2½	5.563	2.875	5
1½ x ¾	1.900	1.050	2½	5 x 2	5.563	2.375	5
1½ x ½	1.900	0.840	2½				
				6 x 5	6.625	5.563	5½
2 x 1½	2.375	1.900	3	6 x 4	6.625	4.500	5½
2 x 1¼	2.375	1.660	3	6 x 3½	6.625	4.000	5½
2 x 1	2.375	1.315	3	6 x 3	6.625	3.500	5½
2 x ¾	2.375	1.050	3	6 x 2½	6.625	2.875	5½
2½ x 2	2.875	2.375	3½	8 x 6	8.625	6.625	6
2½ x 1½	2.875	1.900	3½	8 x 5	8.625	5.563	6
2½ x 1¼	2.875	1.660	3½	8 x 4	8.625	4.500	6
2½ x 1	2.875	1.315	3½	8 x 3½	8.625	4.000	6
3 x 2½	3.500	2.875	3½	10 x 8	10.750	8.625	7
3 x 2	3.500	2.375	3½	10 x 6	10.750	6.625	7
3 x 1½	3.500	1.900	3½	10 x 5	10.750	5.563	7
3 x 1¼	3.500	1.660	3½	10 x 4	10.750	4.500	7
3½ x 3	4.000	3.500	4	12 x 10	12.750	10.750	8
3½ x 2½	4.000	2.875	4	12 x 8	12.750	8.625	8
3½ x 2	4.000	2.375	4	12 x 6	12.750	6.625	8
3½ x 1½	4.000	1.900	4	12 x 5	12.750	5.563	8
3½ x 1¼	4.000	1.660	4				

All dimensions given in inches.

(3) Inside Diameter of Fitting. Inside diameter of fitting at beginning of chamfer

For sizes up to and including 2½ in. ± 1/32 in.
For sizes 3 to 8 in. ± 1/16 in.
For sizes 10 to 18 in. ± 1/8 in.
For sizes 20 in. and larger ± 3/16 in.

(4) Center-to-End of 90 Deg Elbows, 45 Deg Elbows and Tees. Center of fitting to end of chamfer

For sizes up to and including 8 in. ± 1/16 in.
For sizes 10 in. and larger ± 3/32 in.

(5) End-to-End of Reducers, and Lapped-Joint Stub Ends.

For sizes up to and including 8 in. ± 1/16 in.
For sizes 10 in. and larger ± 3/32 in.

(6) Return Bends. Tolerance for "O"

For sizes up to and including 8 in. ± 1/4 in.
For sizes 10 in. and larger ± 3/8 in.
Tolerance for "K" ± 1/4 in.
Tolerance for alignment "F,"
For sizes up to and including 8 in. ± 1/32 in.
For sizes 10 in. and larger ± 1/16 in.

(7) End-to-Face of Butt Welding Caps. Tolerance for "E," sizes up to and including 4 in. ± 1/8 in.
For sizes 5 in. and larger ± 1/4 in.

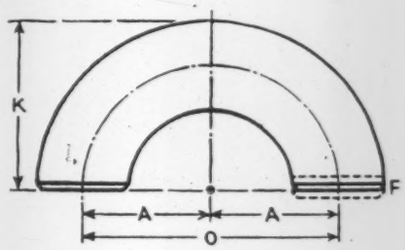


Table 4—Dimensions of Butt Welding 180 Deg Return Bends

Nominal Pipe Size	Outside Diameter at Bevel	Center-to-Center O	Back to Face K
1	1.315	3	2 3/16
1¼	1.660	3¾	2 3/4
1½	1.900	4½	3 1/4
2	2.375	6	4 3/16
2½	2.875	7½	5 3/16
3	3.500	9	6 1/4
3½	4.000	10½	7 1/4
4	4.500	12	8 1/4
5	5.563	15	10 3/16
6	6.625	18	12 3/16
8	8.625	24	16 3/16
10	10.750	30	20 3/16
12	12.750	36	24 3/16

All dimensions given in inches.
Dimension "A" is equal to ½ of dimension "O."
Tolerance for alignment "F," see Par. 9, Sec. (6).

10 Welding Bevel. The recommended practice for the detail of welding bevel shall be as follows:

For wall thicknesses 3/16 to ¾ in., inclusive, 37½ deg ± 2½ deg, straight bevel; land 1/16 in. ± 1/32 in.

For wall thicknesses greater than ¾ in., 20 deg ± 2½ deg U-bevel, 3/8 in. radius; land 1/16 in ± 1/32 in.

Welding ends having thicknesses less than 3/16 in. shall be prepared with a slight chamfer or square in accordance with manufacturer's practice.

Appendix—Dimensions of Welded and Seamless Steel Pipe (ASA B36.10—1939)

Nominal Pipe Size	Outside Diameter	Nominal Wall Thicknesses for Schedule Numbers: Sched 10	Sched 20	Sched 30	Sched 40	Sched 60	Sched 80	Sched 100	Sched 120	Sched 140	Sched 160
⅛	0.405	.....	.....	.....	**0.068**	.....	**0.095**	.....	.....	.....	.....
¼	0.540	.....	.....	.....	**0.088**	.....	**0.119**	.....	.....	.....	.....
⅜	0.675	.....	.....	.....	**0.091**	.....	**0.126**	.....	.....	.....	.....
½	0.840	.....	.....	.....	**0.109**	.....	**0.147**	.....	.....	.....	0.187
¾	1.050	.....	.....	.....	**0.113**	.....	**0.154**	.....	.....	.....	0.218
1	1.315	.....	.....	.....	**0.133**	.....	**0.179**	.....	.....	.....	0.250
1¼	1.660	.....	.....	.....	**0.140**	.....	**0.191**	.....	.....	.....	0.250
1½	1.900	.....	.....	.....	**0.145**	.....	**0.200**	.....	.....	.....	0.281
2	2.375	.....	.....	.....	**0.154**	.....	**0.218**	.....	.....	.....	0.343
2½	2.875	.....	.....	.....	**0.203**	.....	**0.276**	.....	.....	.....	0.375
3	3.5	.....	.....	.....	**0.216**	.....	**0.300**	.....	.....	.....	0.437
3½	4.0	.....	.....	.....	**0.226**	.....	**0.318**	.....	.....	.....	.....
4	4.5	.....	.....	.....	**0.237**	.....	**0.337**	.....	0.437	.....	0.531
5	5.563	.....	.....	.....	**0.258**	.....	**0.375**	.....	0.500	.....	0.625
6	6.625	.....	.....	.....	**0.280**	.....	**0.432**	.....	0.562	.....	0.718
8	8.625	.....	0.250	**0.277**	**0.322**	0.406	**0.500**	0.593	0.718	0.812	0.906
10	10.75	.....	0.250	**0.307**	**0.365**	**0.500**	0.593	0.718	0.843	1.000	1.125
12	12.75	.....	0.250	**0.330**	0.406[1]	0.562[1]	0.687	0.843	1.000	1.125	1.312
14 OD	14.0	0.250	0.312	0.375	0.437	0.593	0.750	0.937	1.062	1.250	1.406
16 OD	16.0	0.250	0.312	0.375	0.500	0.656	0.843	1.031	1.218	1.437	1.562
18 OD	18.0	0.250	0.312	0.437	0.562	0.718	0.937	1.156	1.343	1.562	1.750
20 OD	20.0	0.250	0.375	0.500	0.593	0.812	1.031	1.250	1.500	1.750	1.937
24 OD	24.0	0.250	0.375	0.562	0.687	0.937	1.218	1.500	1.750	2.062	2.312
30 OD	30.0	0.312	0.500	0.625	.....	.....	.....	.....	.....	.....	.....

All dimensions given in inches.
The decimal thicknesses listed for the respective pipe sizes represent their nominal or average wall dimensions. For tolerances on wall thicknesses see appropriate material specifications.
Thicknesses shown in bold face type in Schedules 30 and 40 are identical with thicknesses for "standard weight" pipe in former lists; those in Schedules 60 and 80 are identical with thicknesses for "extra strong" pipe in former lists.
Reprinted from American Tentative Standard for Wrought Iron and Wrought Steel Pipe, ASA B36.10—1939.
[1]Owing to a necessary departure from the old "standard weight" and "extra strong" thicknesses in these two sizes, the new thicknesses are not as yet stocked by all manufacturers and jobbers. Hence, where agreeable to the purchaser and suitable for the service conditions, the old "standard weight" 0.375 in. wall pipe is still available and can be substituted for the 0.406 in. wall, and the old "extra strong" 0.500 in. wall pipe can be substituted for the 0.562 in. wall.

The modern heating and air conditioning installation in the Elgin National Watch Works, Elgin, Ill., is a contrast to the systems found in many factories. In this typical workroom, the exhaust and supply air ducts are shown

Tremendous Field for Improvement in Existing Plant Heating Systems

By Samuel R. Lewis*

THERE is a tremendous field for improvement in the operation and maintenance of existing plant heating systems. One reason is that production too often absorbs the major attention of the regular staff. Another is that many purchasing departments cannot exercise engineering judgment and tend to belittle the advantages of engaging experienced help from outside. Reciprocal purchasing, at the behest of the sales department, frequently is at least "unhelpful" in securing well adapted equipment.

Here, for example, are some of the troubles encountered in a large one story manufacturing plant, which was designed and built for an inexperienced owner to fit a price (the owner employed an operating crew also to fit a price). The high pressure steam boilers were nearly full of mud. Several of the water tubes were clogged completely and by all standards of safety should have blown out and scalded some one long ago. The open feedwater heater looked like the arrow-filled statue of St. Sebastian since, as leaks developed due to corrosion in its shell, they drove in sharpened hardwood plugs to stop them.

There were no stop check valves on the steam take-off pipes at the boilers, and the angle valves they had were not tight, either around their stems and gaskets or when closed to stop steam flow. They had alleged boiler insurance and the city employed a boiler inspector, but neither inspector apparently was influential.

The steam header above the boilers was supported by propped up wood scantlings, and it squirted steam at several corroded fittings. The two boilers were set with water levels at different heights, so that the engineer was kept very busy making minute adjustments of the feed valves so as to divide the water fairly whenever both boilers were on the line. Water supply for the boilers had been taken at various times from a shallow well, impregnated with organic debris, from city mains, and from the nearby muddy and polluted river. Much to my surprise I found piped up cross connections (Fig. 1) between all three systems so that untreated and filthy river water could be supplied to the drinking fountains and also could enter the city mains and infect the people of a whole district.

The mud in the boilers largely was caused by using river water. The shallow well water was much cooler

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than the city water and therefore was piped hundreds of feet to drinking fountains in strategic locations out in the plant. This piping was situated in most cases between the unplastered ceiling rafters, without pipe insulation and without return circulation, close against the uninsulated roof. In consequence, it became so warm in summer as to be undrinkable unless running continually. The fountains, having acquired the continuous running habit, kept it up even on a September morn when I inspected them, and no doubt also must run continuously all winter to keep from freezing.

I was told that, as a result of the drinking fountain leakage, the pump and motor and pneumatic tank of the shallow well system were too small and were to be doubled in capacity. It occurred to me that an interesting study might be made of the comparative cost for investment and operation of, say, 10 small electric drinking water refrigerators using the assuredly clean city water.

I cleaned up the water matter by stipulating that all connections with the dirty river water be deleted, not just by closing valves, but by tearing out the pipes and by abolishing entirely the river water pumps. The city water, which is excellent for steam boilers, is to be used for boiler feed. They probably commenced to use river water because the steam and return piping leaked so badly that the cost of metered city water seemed high.

The vacuum pump serving the heating system ran continuously despite some alleged attention to the thermostatic return traps. The suction piping was all under the concrete floor, buried in the peat of the original swamp on which the building was built, so that the pipe was always damp due to capillary action. We found it necessary to replace all of the buried return mains, around 2000 linear feet, with new overhead vacuum return mains before any sub-atmospheric pressure could be developed by the vacuum pump. This involved changing the heating methods from using the wall radiators below the windows, in many departments, to overhead unit heaters. Considerable fuel economies followed this change, since it resulted in a lower temperature of the air directly below the uninsulated roof.

In another case I inspected a 17 story, 10 year old apartment building. It had insulated overhead steam mains in an attic below an uninsulated roof. The mains were poorly covered originally and the insulation had not been well maintained. I noticed galvanized sheet steel gutters suspended below many of the pipes and valves. It appears that the poorly anchored mains, installed without adequate consideration of expansion, kept developing small leaks in the fittings, and that the stems of such few valves as were furnished eventually would leak. With something like 250 tenants the engineer proclaimed that he could not shut down in winter to make tight the leaks, and since the pipes did not leak in summer he did not bother then to repair them. The easiest emergency recourse to save the top story ceilings was to wire a sheet steel gutter under each leak, leading the water to downspouts. The gutters were especially valuable in summer anyway, since the poorly insulated cold water mains in the attic frequently condensed water out of the air, and would drip.

There were no sub-dividing valves on the attic cold water mains and the engineer thought maybe the condensate must be from leaks. He dared not shut off the water for a time long enough to demonstrate the location and the reason for each leak. He thought it somewhat strange, however, that the cold water mains mysteriously ceased "leaking" in winter. Need I say anything about the uses of insulation on attic ceilings or roofs, or about the advantages of maintenance of existing insulation?

There was another case in which a big steel downdraft firebox boiler, which originally was ample in capacity, seemed to have experienced unaccountable fatigue. Investigation proved that as the years went by the engineers changed until one was hired who had no ideas about the unique processes of firing such boilers, which have an upper grate made of 2 in. water tubes rather widely spaced. He undertook to fire the boiler after the erroneous methods formerly taught for heavy duty locomotives, spreading the green coal in frequent thin layers above the incandescent mass of coals on the upper grates. In stoking and cleaning, he punched some holes through barrier *A*, Fig. 2. This bypassed the cold air intended for combustion directly to the heat absorbing surfaces.

Of course, the city smoke prevention bureau eventually intervened. Accordingly they bought semi-anthracite coal and immediately the boiler became still smaller. This kind of coal in a large downdraft boiler tends, when heated, to cake together and to stop the downward passage of the necessary air through the coal to reach the active fire zone. This situation persisted for several years before being discovered and corrected by stopping the leaks, changing to bituminous coal with a thick fuel bed and long firing intervals.

There was a big sectional cast iron steam heating boiler which originally did badly enough with coal, because of insufficient combustion chamber capacity and too rapid chilling of the released gases. They installed a satisfactory type of industrial oil burner. The boiler still seemed to be too small for the job and the breeching seemed to be too hot. Then they installed within the firebox spiral copper coils, one on each side of every section (Fig. 3). These water tubes were expected to improve the internal water circulation and to increase the heat absorbing area. They caused, however, so low a combustion chamber temperature as to prevent burning the oil, which tended to condense on the tubes and to drip and carbonize all over them.

We learn by experience—our own and others. Mr. Lewis gives some examples—horrible and otherwise—of things he's run across while checking up plant heating and piping systems that indicate the need for and possibilities of making improvements. Trouble with an otherwise satisfactory installation is often due to some fault which is easily corrected—an improper piping layout, for instance, a blast heating coil carrying the weight of piping for which it was not designed, lack of insulation, an incorrect firing method, etc. . . With increased industrial activity, weak points in a plant service (such as heating) show up just as expensively as they do in the production process. Part of "industrial preparedness" is putting present plant facilities in good working order

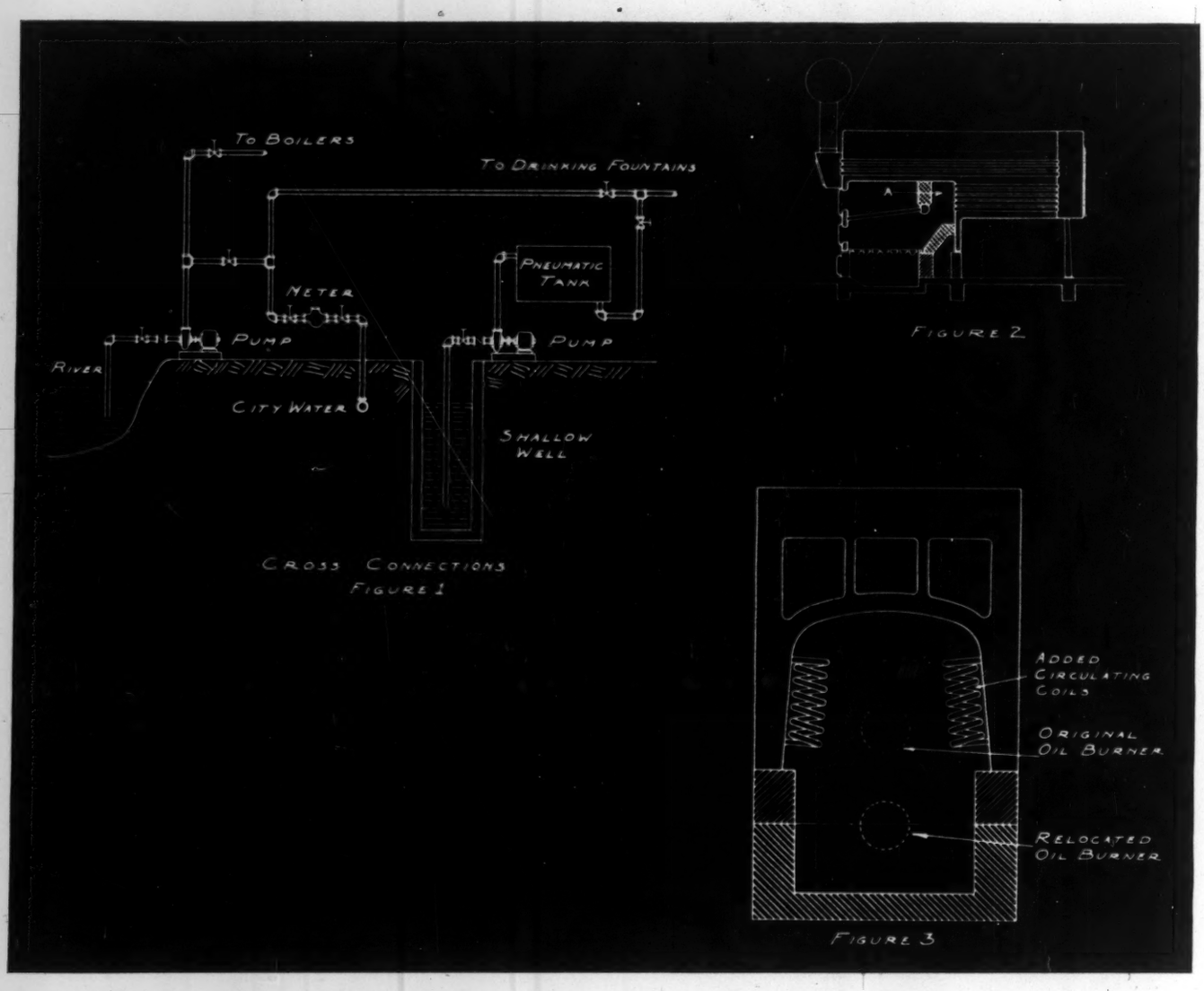


Fig. 1—"Much to my surprise, I found cross connections between all three systems so that river water could be supplied the drinking fountains and could enter the city mains." . . . Fig. 2—"In stoking and cleaning, the fireman punched some holes through the barrier marked *A;* this bypassed the cold air intended for the combustion directly to the heat absorbing surfaces." . . . Fig. 3—"These added coils were expected to improve the water circulation and increase the heat absorbing area. They caused, however, so low combustion chamber temperatures as to prevent burning the oil, which tended to condense on the tubes"

This plant, however, has been operating very satisfactorily for four years, since the combustion chamber volume was increased, with the oil burner lowered proportionally, and since the oil piping was changed to encourage the delivery of warmer oil to the burner.

A new oil burner was installed in the boiler of a very large old residence having a thermally circulating hot water heating system. The thermostat which controlled the oil burner operation was placed successively in various rooms, without success. The temperature of the room in which the thermostat was situated could be controlled, but if this room was naturally warm, with little exposure to cold, there would be many other rooms which were too chilly. They then would move the thermostat to a room having relatively great exposure to cold, and found rooms overheated before the oil burner was shut down.

One reflects that only in very favorably designed houses of relatively small size, having a symmetrical arrangement of rooms, can favorable results be expected from control of an oil burner by a single room-located thermostat. We changed this particular installation by installing five hot water circulating pumps, each for a separate zone or orientation. Operation of each pump is controlled by a zone thermostat, while operation of the oil burner responds to an adjustable thermostat in the water leaving the boiler.

Not everyone has learned that the enclosed convectors designed to replace tubular exposed radiators are tested and rated with steam. This is done because we do not yet rate heat transmitters for output, or accomplishment, but continue to rate them by *input;* this being the amount of steam a given device will condense. It is like rating the work done by a WPA-er by how much he eats.

Anyway, there are some unsatisfactory hot water heating systems where convectors instead of radiators were installed, which can be made quite satisfactory heating systems merely by increasing the water temperature to approximately that of steam, in cold weather. With a relatively slight temperature difference between the water in the convector and the air, the air flow is too sluggish to serve. With tubular radiators, however, the same water temperature would have been ample.

How Much Power Is Used for Air Conditioning?

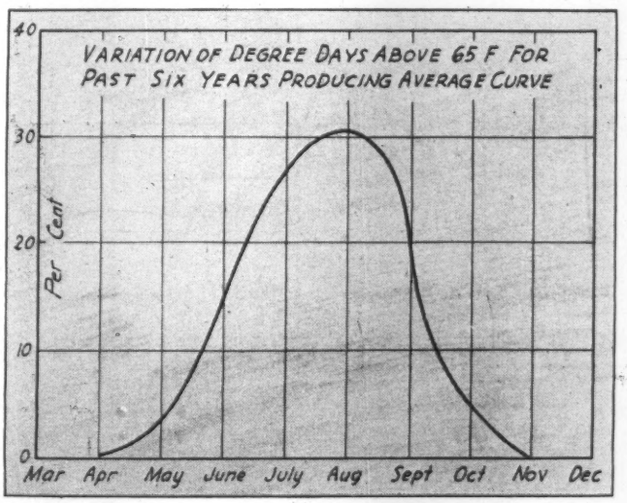
. . . . . Stephen L. Gregg* answers the question for the average installation in Washington. D. C., with data obtained for systems in various types of commercial establishments. Figures on the variation of power consumption during the months of the cooling season, and its relation to degree days above 65 F, are also presented. . . . . Similar data on Kansas City, Mo., and Chicago installations have previously been made available, and the author expresses the hope that figures for other cities will be compiled

AS the number of air conditioning installations grows there is increasing need for accurate knowledge of operating costs. Several years ago it was felt that some information on electrical consumption of air conditioning equipment installed in Washington, D. C., could be compiled; such data are given here.

It might be interesting first to note the amount of air conditioning installed in Washington. The figures are based on the commercial and residential load only. At the end of 1938 the figure was 0.0353 horsepower per capita, and this increased to 0.0439 as of September 1, 1939. If we add to this the air conditioning installed in government buildings (but not including those installations which are served by the Capitol power plant) the figures become 0.0824 for the end of 1938 and 0.0830 for September 1, 1939. Corresponding figures for other cities are, respectively, as follows: New York (Manhattan and Bronx), 0.0265 and 0.0295; Chicago, 0.0209 and 0.0222; Philadelphia, 0.0157 and 0.0171.

The original thought in our study was to divide the field into different classes based upon the size of the equipment. Upon investigation, however, it was found that this was not practical, but that it would be of more benefit to break it down into installations classified as to types of businesses.

Apartment Houses—The first classification is apartment houses. There are 10 apartment houses in Washington where the owner has installed equipment for the benefit of his tenants. Seven of these installations were made in new buildings during construction; the others were made in existing buildings in connection with other modernization work. In the new building group, one installation comprises self-contained units, and during the past summer it was found that the power consumption averaged 1345 kwhr per hp per season. Complete season records were not available for all of the remaining new installations, but for those which could be obtained the consumption averaged 723 kwhr per hp per season. For the apartment houses which made installations in connection with a modernization program (all self-contained units of various sizes) the records show the average power consumption has been 922 kwhr per hp per season.



Barber and Beauty Shops—The next classification is barber and beauty shops. There have been many such installations made, especially in beauty shops, although in a number of cases the air conditioning had been connected to an existing meter with the lights and other equipment so that accurate records could not be obtained. The figures for those installations where data were available are shown in Table 1.

Drug Stores—A more or less specialized classification, or at least one which has air conditioning operating hours peculiarly its own, is the drug store. The store operating day is a long one, averaging about 15 hr. In many locations in Washington, there are three distinct load periods which occur during the operating day. All this, of course, tends to make the kilowatthour consumption much higher than for other types of occupancy, with the exception of the restaurant (See Table 1).

Funeral Parlors—Funeral parlors, with the exception of one or two installations, are a type of occupancy where the operation of equipment is quite erratic. Some days it is not used at all, while on others it is operated all day long. It is therefore not surprising to find the averages for this type of occupancy at a low figure, as shown in Table 1. In 1938 and 1939 installations were made in two of the larger establishments which have quite a number of funerals. If these two installations are taken out of the averages, the figures become those shown in parentheses in the table.

Hotels—The hotel classification must be broken into several minor divisions based on the type of installation. It happens that there are available figures only on one or two installations for each division. First, there is the hotel that is conditioned entirely or partially by self-contained units. During the past season, this consumption has averaged 855 kwhr per hp. Now, let us note

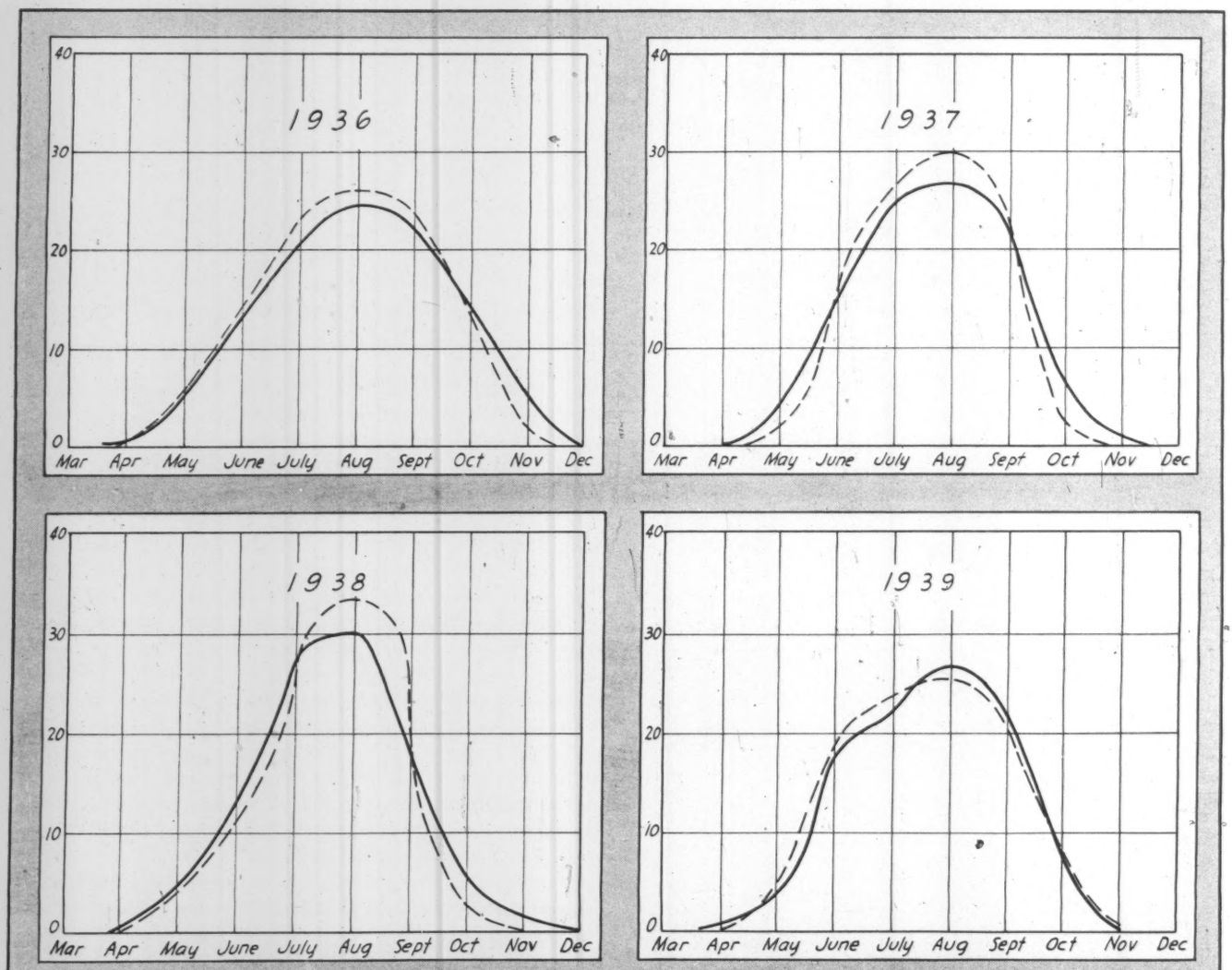
*Power Engineer, Commercial Engr. Dept., Potomac Electric Power Co.

the figure for the hotel that has been conditioned entirely or partially by a central station installation with duct distribution. This figure has been obtained from installations where the air conditioned public space has not been enough of a factor to be noticeably influential, as no figures were available where the air conditioning was separately metered. For this type of installation the consumption has averaged 1676 kwhr per hp for the season. A third type of hotel installation is one in which well water is available for use in conjunction with the usual type of direct expansion equipment. In this type, the figure is 1125 kwhr per hp per season.

The variation in consumption is rather interesting. In the case of the hotel utilizing self-contained units the consumption is lower than that of the hotel with the conventional installation because the units are operated only when the rooms are occupied. This can be checked fairly closely as the hotel operates under a system of room clerks on each floor. The hotel utilizing well water has a lower consumption than the conventional installation because advantage can be taken of its refrigerating effect, thus reducing the requirement for installed compressor capacity.

Movie Houses—There have been rapid strides made by the local movie house operators in modernization and construction of new theaters in the neighborhood field. Nearly all of these houses open around 5:30 p. m. and continue on through until about 11:00 p. m., and also have matinees on Saturday and Sunday. Average figures are shown in Table 1.

Offices—An important classification, and one which will grow during the next few years, is that of the private office or suite of offices. Here again, we must break down our classification into several divisions. First, we have the suite of offices which has been conditioned with a central system for summer operation only (see Table 1). Next, we have a similar type of installation, but for year 'round operation, the figures for which are tabulated. It is interesting to note how small the increased consumption is to operate the system year 'round and provide proper air conditions at all times. Still a third breakdown of this group is that of the instal-



VARIATION OF DEGREE DAYS ABOVE 65 F AND MONTHLY KILOWATTHOUR CONSUMPTION EXPRESSED AS A PERCENTAGE OF THE TOTAL FOR THE SEASON FOR DRUG STORES

——— Kw hr consumption
– – – – Degree days

lation consisting of only small self-contained units (see table).

Stores—Let us now deal with a classification covering all of the small stores, including dress shops, fur stores, haberdasheries, jewelry stores, millinery stores, shoe stores, book stores, opticians, etc. It was found when assembling data on these various types of occupancy that the kilowatthour consumption was quite similar for each member of the group. Consequently, it is felt that the average for the group given in Table 1 presents a fair picture for one and all.

Restaurants—This group cannot be dealt with as a whole for we have a variation in hours of operation as well as year 'round and summer-only installations.

For the summer-only installations and for restaurants which are open 24 hr per day, figures are available (Table 1) for the three years previous to the past summer. Due to unavoidable conditions, these figures could not be obtained in 1939. Figures are also given for restaurants open only for three meals a day, for the restaurant open from 7:00 a. m. to 2:00 a. m., and for a year 'round installation for restaurants open from 7:00 a. m. to 2:00 a. m.

These figures on kilowatthour consumption per horsepower per season are based upon the total air conditioning horsepower installed for the given location, not on compressor horsepower only. The figures for each year are the average for the installations in that group and are not for one installation only.

Considerable interest is being shown in the storage type of installation, which operates over a longer period during the 24 hr day and stores up, in a properly insulated tank, cold water or ice for use during air conditioning load periods of the operating cycle. At the present time, there is only one such installation in Washington (a theater), which has been in operation for several years. The following data indicate the advantage of this type of system. Comparable figures are given for a conventional installation in another theater for two seasons, 1937 and 1938.

	Storage	Non-Storage	Storage	Non-Storage
Number of seats	1600	2372	1600	2372
Horsepower installed	125	290	125	290
Maximum demand, kw	86	275	92	255
Kwhr per seat per season	59	81	45	65
May to Oct. load factor (A. C. only)	37%	23%	21%	17%
Annual load factor, entire bldg	27%	18%	26%	18%

As shown in Table 1, the kilowatthour consumption has varied each year. There is also the question of the variation of the consumption during the operating season. After some figuring by the trial and error method, it has been found that the kilowatthour consumption varies as the number of degree days *above* 65 F.[1] To illustrate this variation, the several curves for drug stores show the variation in monthly kilowatthour consumption as a percentage of the total, and variation of the monthly degree days as a percentage of the total. The variation in the degree days for the past six years is also consolidated and plotted. From this we can obtain an average curve. With the use of the average curve and the data relative to the consumption for a particular type of occupancy we can approximate fairly intelligently the annual kilowatthour consumption and the monthly variation of this for any given installation. Of course, it must be borne in mind that we are dealing in averages, for every installation will have its own peculiarities which will affect the results obtained.

[1] For any one day, there exists as many degree days as there are degrees Fahrenheit difference in temperature between the average outside temperature and 65 F.

Table 1—Average Kilowatthours of Electricity Used per Horsepower per Season for Air Conditioning, Washington, D. C.
(Data on Apartments and Hotels Given in Text)

	1936	1937	1938	1939	General Average
Barber and beauty shops	.....	883	808	819	836
Drug stores	1390	1173	1102	1346	1253
Funeral homes	275	181	314 (229)[a]	367 (181)[a]	284 (205)[a]
Neighborhood movie houses	.....	422	378	521	440
Offices—Summer central system[e]	325	540	668	784	579
Offices—Year 'round central system	.....	572	856	944	791
Offices—Small self-contained units	1300	.....	1233	1271	1268
Small stores[b]	807	689	616	757	717
Restaurants[c]	1732	1469	1235	.....	1479
Restaurants[d]	849	705	526	696	694
Restaurants[e]	1215	953	796	916	970
Restaurants[f]	1487	1278	1255	1435	1364

Note—Since one horsepower operating one hour uses very close to one kilowatthour of energy, these figures indicate approximately how many hours during the season the average installation has been operated at the equivalent full load.

[a] Figures in parentheses do not include two large funeral homes which have an exceptionally large number of funerals.

[b] Figures include dress shops, fur stores, haberdasheries, jewelry stores, millinery stores, shoe stores, book stores, opticians, etc.

[c] Summer-only installations in restaurants open 24 hr per day.

[d] Summer-only installations in restaurants open only for three meals a day.

[e] Summer-only installations in restaurants open 7:00 a. m. to 2:00 a. m.

[f] Year 'round installations in restaurants open 7:00 a.m. to 2:00 a.m.

Need of Education and Instruments

Speaking of "results obtained," there are two very important contributing factors which if properly handled will do much toward lowering air conditioning operating costs. The first and most important is the complete education and instruction of the owner of the equipment as to its proper operation. The second is the furnishing and installing of necessary indicating and control instruments. Both of these have been grossly neglected in the "average" installation. A survey of 53 air conditioning installations made about two years ago produced some most interesting results. Of the 53 installations visited, only seven were operated under the supervision of an operating engineer. Of the remaining 46, the operators of approximately 85 per cent of them indicated very definitely that they had a vague general idea of air conditioning, but that they were quite confused about many details. The survey showed that there existed 19 different plans for the setting of thermostats and operating the systems. Thirty-eight of the installations had no means at all of knowing what the outside temperature was. It can be appreciated how operating under such conditions as these will affect the kilowatthour consumption of the system adversely.

In conclusion, there is one recommendation that can be made and that is that the electric service companies (in coöperation with the members of the air conditioning industry in their own localities) compile data similar to that given here. Such information has been prepared by Anson D. Marston,[2] of Kansas City, Mo., and figures for Chicago[3] have been published. If more data are made available throughout the country there will be a much more intelligent basis for the consideration of electrical operating costs in various localities.

[2] Paper presented at semi-annual meeting of American Society of Heating and Ventilating Engineers, June, 1937, and published in ASHVE *Journal Section*, Heating, Piping and Air Conditioning, August, 1937, pp. 513-519.

[3] Electricity Used by Air Conditioning, by William P. Rock, Heating, Piping and Air Conditioning, April, 1937, pp. 239-241.

Discoloration at Air Outlet Grilles Caused by Static Charges, Study Shows

By H. C. Murphy*

DISCOLORATION of walls and ceilings adjacent to air discharge openings in rooms has sometimes been a source of trouble. There are a number of factors which may enter into this situation, some of which have only recently been understood.

No air cleaner is 100 per cent efficient in removing smokes and fumes as well as dust from the air. Commercially available air filters or air washers may give entirely satisfactory service in the removal of solid air impurities of the order of 10 microns (the smallest particle visible to the naked eye), but they are not designed to remove smokes and fumes. The National Bureau of Standards reports that electric precipitators have maximum efficiencies of from 85 to 95 per cent against smokes, fumes and similar air impurities when tested by the discoloration method developed by the bureau. The efficiencies of the usual commercially available air filter against such impurities are much lower. Smokes and fumes, however, which pass through the ordinary cleaners in the form of gases can be shown to be responsible for objectionable discoloration of walls and furnishings.

Microscopic Particles Agglomerate

Careful tests made immediately behind the air cleaners frequently disclose no measurable solid impurities capable of causing such discoloration. It may be observed, however, that a short distance in back of the air cleaners, the air in the duct sometimes shows an increase in the number of measurable solid impurities.

In general the amount of these impurities seems to increase with the length of the duct and with the number of sharp changes in direction. This phenomenon is due to the agglomeration of particles of microscopic size which pass through the air cleaner in the form of gases or fumes. Subsequently, these particles coalesce or agglomerate into larger particles which are measurable with standard instruments for dust determination. The force causing this agglomeration has been identified as static electricity. The source of the energy, however, until recently was unknown.

The Underwriters' Laboratories recently published a research bulletin on generation of static electricity in blower systems (Research Bulletin No. 8, April, 1939). They reported that their investigations indicated static charges of considerable magnitude were sometimes generated in blower systems. Their principal concern was the possible fire hazard set up by these electric charges, but these facts also seem to account for the agglomeration of small particles in the clean air duct and the discoloration at outlet grilles. The investigators summarized their findings as follows:

From these tests it appears that air practically free from solid or liquid particles is not perceptibly electrified under conditions ordinarily obtaining in blower systems. If dust or lint is present in appreciable amounts, static charges of a magnitude capable of causing ignition by spark discharges may be generated. Voltages actually observed ranged from 100 to over 10,000. It was observed that within certain limits the static charge increased in magnitude with increase in the concentration of dust or lint, fineness of particles, velocity of air stream, and decrease in humidity.

The investigators recommended that duct systems be electrically grounded to prevent the accumulation of static charges. They stated:

Although grounding of the ducts cannot be depended upon under all circumstances to eliminate static electricity, if all joints of metal ducts are electrically bonded, and the entire system is properly grounded, the static hazard will be minimized.

Our present knowledge further emphasizes the desirability of locating the air filters in front of the fan, as air which is relatively free from dust or lint is not as likely to set up static charges in passing through the fans and ducts as is uncleaned air.

Location of Grilles and Intakes

Even with air which is 95 per cent free from smokes, fumes and solid impurities the air discharged will eventually discolor outlet grille openings and it is good practice to place outlet grilles so that the air is not discharged directly against white walls or ceilings. This

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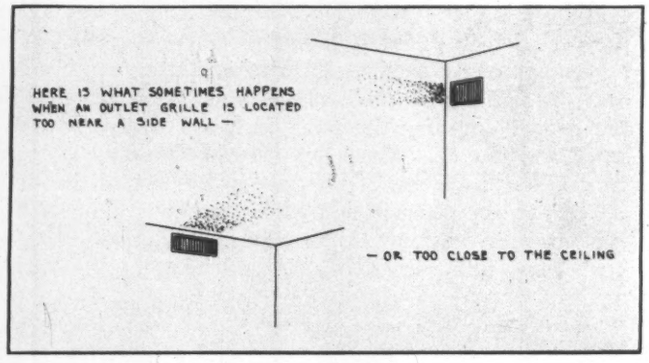
Discoloration of walls and ceilings adjacent to the air discharge openings in rooms is sometimes a source of trouble in air conditioned or ventilated buildings. While careful tests made immediately behind air cleaners may disclose no impurities capable of causing such discoloration, the air farther along in the duct may show an increase in the measurable solid impurities. The author believes this is due to agglomeration of the microscopic particles because of the static electricity charges generated in a duct system. Research has shown charges of considerable magnitude are sometimes generated in duct systems. . . . Suggestions on the location of grilles and air intakes are given



*Vice-president, American Air Filter Co., Inc. Member of Board of Consulting and Contributing Editors.

is especially important with acoustic ceilings or rough wall surfaces.

If, when the system is designed, adequate consideration is given to the location of outside air intakes, the load which the air cleaners are called upon to handle can sometimes be materially reduced. Some years ago I measured the air impurities on the street level at the Woolworth building in New York City; I then took dust counts at the 5th, 10th, 15th and subsequent floor levels. The number of measurable dust particles decreased at the higher levels but the volume of smokes and fumes increased. The outside air intake should be situated high enough to escape excessive dust concentrations at the street level but below the level of adjacent smoking chimneys or incinerators. A pent house intake should be well above the parapet wall as the dust concentration at the roof level is usually high. The intake should preferably be on the side of the building away from the prevailing winter winds. Intakes from sidewalk grilles, pits and areaways are always undesirable. Intakes in narrow alleys or spaces between high buildings frequently encounter clouds of dust kept in suspension by whirling air currents.

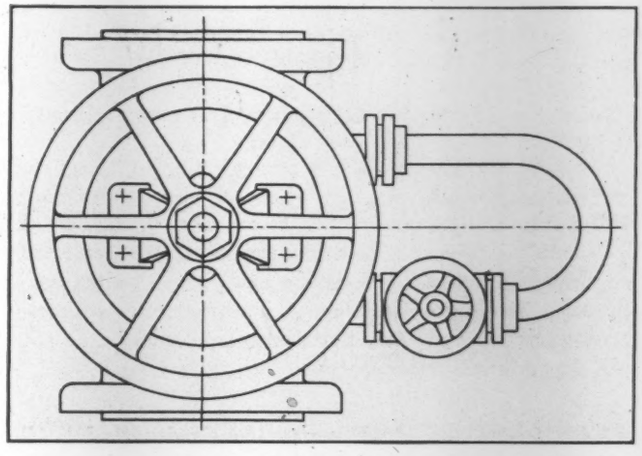
In locating air intakes, the question of nearby fire hazards should be considered. If the intake is situated so that smoke or fire from the burning of an adjacent building may be drawn into the system it may result in penalties from the fire underwriters or the necessity of installing automatic fire shutters and similar safety measures.

Standard Bypasses for Main Line Control Valves

By **John J. Harman***

WHEN a main line valve in a piping system is closed for any great period of time that portion of the pipe line which is out of service will soon drop to approximately atmospheric pressure and temperature. When it is desired to open the valve again, great care must be taken to control the process so as to prevent a sudden and violent upward surge of pressure and temperature which might endanger the stability of the pipe line. Especially in handling a hot fluid—like steam—the process must be slow enough to permit the cold and empty pipe line to warm up and build up its pressure gradually, in order to avoid condensation, water hammer, sudden local expansion and other undesirable conditions. Building up the pressure gradually has the additional advantage of allowing time to discover any open valves that should be closed and any leaky joints that may have become loosened while the pipe line was out of service. Equalizing the pressure on the two sides before opening the main valve is also an advantage in operating the valve, because the valve opens more easily, wire drawing is avoided, and scraping and scoring of the valve seats is prevented.

For these reasons it has been customary practice for many years to install a relatively small bypass valve around main control valves for the purpose of equalizing or partially equalizing pressure and temperature on the two sides before opening the main valve. It has been found good practice to install bypass valves on all main control valves sizes 4 in. and larger. However, due to variations in service conditions, the size of bypass used for a given size of main control valve in actual practice has varied through a rather wide range, depending on the ideas of the individual pipe line designer and on the differences in service conditions. For instance, on steam service requiring a relatively long time to heat up the cold line, a comparatively small bypass valve is indicated. On the other hand for cold water or gas service where the purpose of the bypass valve is mainly that of equalizing the pressure on the two sides of the main control valve, a larger bypass valve is advantageous in order to shorten the time required for opening the main valve.



Bypass for a gate valve. Bypass may be on opposite side of valve or on bottom

Table 1—Standard Bypass Sizes, Series A

Main valve size, in	4	5, 6 & 8	10 to 24
Bypass size, in	½	¾	1

Series A dimensions are used in steam service for warming up before the main line is opened and for balancing pressures where the lines are of limited volume. They are in common use on ferrous globe and angle valves and on steel gate valves.

Table 2—Standard Bypass Sizes, Series B

Main valve size, in	4	5-6	8-10	12-14	16-20	24
Bypass size, in	1	1¼	1½	2	3	4

Series B dimensions are used in lines conveying gases and liquids where the larger bypass valve facilitates the balancing of the pressure on both sides of the main valve before opening it.

In this connection, however, it is of interest to note that while the size of bypass valves in common use has varied through a rather wide range it has been found by means of a careful study of the situation that two series of bypass sizes will cover most all conditions occurring in practice. The Manufacturers Standardization Society of the Valve and Fittings Industry therefore issued its Standard Practice No. SP-5-1937, in which are given standard bypass sizes as shown here.[1]

Where peculiar service conditions warrant consideration of a special oversize bypass valve, it is recommended that the bypass valve should be installed in a branch line.

*General Secretary, Manufacturers Standardization Society of the Valve and Fittings Industry, and Secretary, ASA Sectional Committee B16 on Standardization of Pipe Flanges and Fittings. Member of Board of Consulting and Contributing Editors.

[1]For complete list of MSS Standard Practices, see Standardization in the Valve and Fittings Industry, by John J. Harman, HEATING, PIPING AND AIR CONDITIONING, March, 1938, pp. 180-181.

Corrosion in Steam Heating Systems

Eliminating Deleterious Gases from Steams

By Leo F. Collins* with Everette L. Henderson†

IN Table 6 are shown analyses of the steams produced in 12 different boiler plants. These include both central heating plants and so-called isolated boilers. In a few instances, where deaeration is employed, little or no oxygen was found, but at all locations some CO_2 was detected. These two gases are the only ones found which are capable of producing corrosion. Since (as has been shown) they are the basic causes for most corrosion troubles, it would seem that the aim should be complete elimination of both gases. But while this may be true for other than scientific reasons, it is indicated by the experimental data that tolerable limits will suffice adequately to minimize corrosion in steam heating systems.

Tolerable Limits for Oxygen and Carbon Dioxide

As will be shown later oxygen can be completely eliminated (from a practical point of view) with mechanical deaerating equipment. It can also be sequestered by chemical means. The welfare of steam generating equipment requires practically complete elimination of this gas from the feedwater. Hence from an overall standpoint it is evident that oxygen should be as completely removed as is possible.

Table 6—Analyses of 12 Steams (So Cond[illegible] All Entrained Gases Are Dissolved

Location Code No.	Oxygen (O_2) cc/L	Carbon Dioxide (CO_2) ppm	pH Value
25	0.66	—	6.3
24	0.09	1	6.7
19B	0.30	2	6.4
26	0.45	3	5.4
22B	0.64	4	5.5
27	1.76	4	5.3
29	1.36	8	5.4
28	0.79	11	5.2
30	3.61	14	5.3
17	<0.03	16	5.4
19	0.40	25	5.2
18	0.34	31	5.2

Carbon dioxide, on the other hand, cannot be completely removed on a commercial scale by any known simple method. Nor is this necessary. The critical pH value for carbonic acid corrosion is 5.9. The theoretical pH value of a condensate is 5.9 or less when more than 2 ppm of CO_2 is dissolved. Then too, the curves of Fig. 5 showed that "active" corrosion does not occur when the CO_2 content of freshly formed condensates is 2 ppm [parts per million] or less. It seems reasonable to conclude, therefore, that if the intent is to produce a steam which will not cause "active" corrosion, even though it is condensed so as to retain all entrained gases, the maximum permissible CO_2 concentration is 2 ppm.

It does not follow that steams containing more CO_2 than this amount will cause active corrosion on a broad scale. Only in rare cases are steams condensed, in actual practice, so as to retain all entrained gases. In most heating equipment less than one-half of that entrained is dissolved in the condensate. Moreover, production of a steam containing not more than 2 ppm of CO_2 will materially increase production costs. These facts must be given consideration when corrosion problems are being considered. The authors' personal opinions are that steams containing up to 5 ppm of CO_2 will be satisfactory except in the most unusual instances.

Sources of Entrained Gases

The primary source of either or both gases is the feedwater, particularly the make-up water supply. Supplementing the primary source may be (and quite often is) the chemicals used for boiler water treatment, and in some cases peculiarities in the arrangement of the boiler plant water cyle which accumulates gas that otherwise will escape to the atmosphere.

Dissolution of Air in Pure Water—The amount of any gas which will dissolve in pure water is limited, and depends upon the nature of the gas in the contacting vapor phase, and the temperature of the water. This generalism (known as Henry's Law) holds for dilute solutions provided the dissolved gas does not react chemically with the water. Dalton has shown the solubility of individual gases in a mixture of gases to be directly proportional to their partial pressures, the solubility of each gas being nearly independent of the presence of the other. The solubility** of oxygen in pure

The question of eliminating deleterious gases from steams is the subject discussed this month in the Collins-Henderson treatise on corrosion in steam heating systems. It has been shown that oxygen and carbon dioxide are the basic causes for most corrosion troubles, and it is thus indicated that to minimize corrosion, means should be employed to keep their concentration within tolerable limits. . . . The comprehensive treatment of heating system corrosion, of which this month's discussion is a part, is based upon 15 years of research work for The Detroit Edison Co. Engineers concerned with operation and maintenance of building heating systems, district heating engineers, and industrial piping engineers will find the information as useful as will designers and installers of heating plants. . . . Because of its length, it is necessary to publish this material in serial form; the reader is accordingly cautioned not to pass final judgment on it until its publication has been completed

*Chemist, The Detroit Edison Co.
†Professor of Chemistry, University of Detroit.

Part 5. Part 1 was published in Heating, Piping and Air Conditioning, September, 1939, pp. 539-542; Part 2 in October, pp. 620-622; Part 3 in November, pp. 675-677; and Part 4 in December, pp. 735-738.

**Solubility of a gas is the ratio of concentration of gas in the solution to the concentration of gas above the solution.

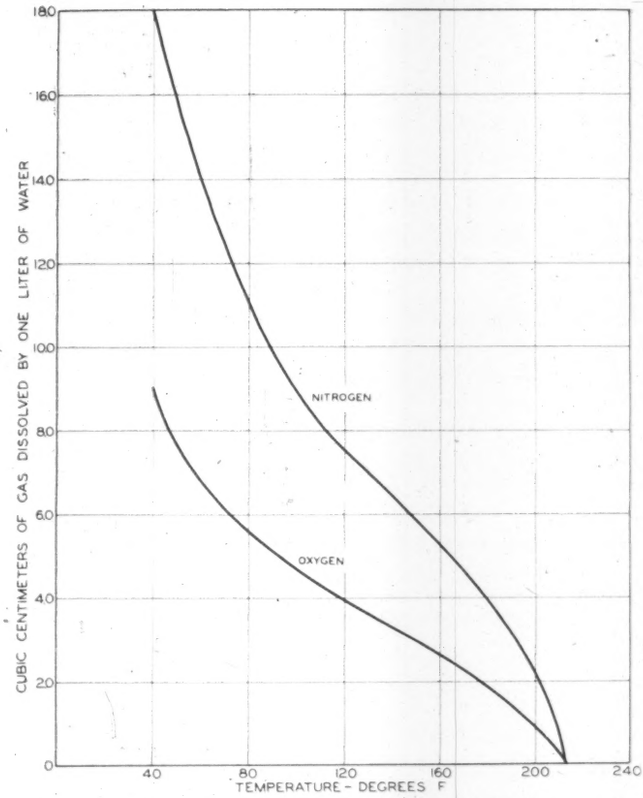


Fig. 13—The content of oxygen and nitrogen (air) in pure water in contact with the atmosphere at various temperatures

water is nearly twice that of nitrogen, and since the solubility of one gas is unaffected by the presence of the other, the air dissolved in water is much richer in oxygen than is that in the contacting gas phase. In Fig. 13 is shown the amount of oxygen and nitrogen which will be dissolved by pure water at temperatures up to the atmospheric boiling point when in contact with the normal atmosphere. For practically all plants these relationships hold because no substances are present in the feedwater in sufficient quantities to be of material influence.

Dissolved air, therefore, represents the entire potential source of oxygen. There are no dissolved materials normally present in feedwaters which decompose with the liberation of oxygen nor does water decompose sufficiently, even at extremely high boiler pressures, to be a matter of concern. Nitrogen, being inert, does not enter the picture.

Carbon Dioxide Content of Feedwaters—Carbon dioxide is invariably present in feedwaters both as a dissolved gas and in chemical combination, particularly as the carbonates of alkaline earth and alkali metals.

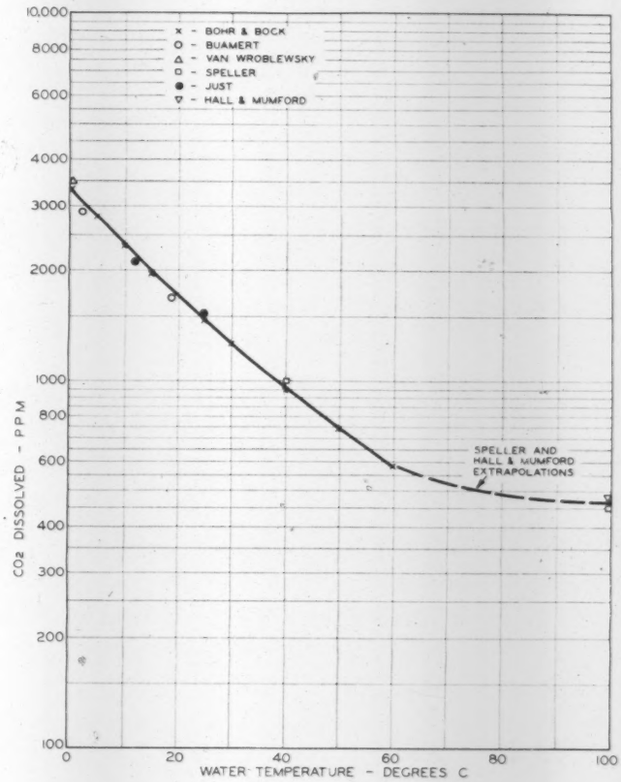
With regard to gaseous CO_2, considerable uncertainty exists concerning its solubility; especially is this true for temperatures above 140 F. In Fig. 14 is shown a resumé of published data relative to the solubility of the gas at a partial pressure of one atmosphere.

Those familiar with the chemistry of boiler water treatments are well aware that the amount of gaseous CO_2 present in most feedwaters contributes only a small fraction of the total amount normally entrained with the steams. By far the greater amount is produced as a result of thermal hydrolysis of calcium, magnesium, and sodium carbonates within boilers.

Accumulation of Gases in a Feedwater Cycle—In most sizable boiler plants the water is heated prior to its introduction into the boilers. In many cases this is accomplished by bringing steam directly into contact with the water in a feedwater heater. It is also desirable at times to preheat in more than one step. In such a cycle the usual practice is to vent the heater operating at the highest temperatures into the next lowest stage. When this is done, if all the gases are not removed by the heater operating at the *lowest* temperature, it is possible to accumulate abnormally large quantities of gas. The ultimate result of such accumulations is to prevent elimination of gases that otherwise will occur. A striking example of an accumulating cycle was found during the course of our studies.

A diagramatic sketch of this cycle is shown in Fig. 15. During the time the studies were being made the boiler input consisted of about 25 per cent returned condensate and the remainder fresh water. The make-up contained about 85 ppm of calcium bicarbonate, 40 ppm of magnesium bicarbonate, and about 2 ppm of free carbon dioxide. Approximately 25 ppm of sodium carbonate was proportioned to the water in the open feedwater heater. The effluent from the open heater was pumped into another heater operating at about 356 F. Because of the agitation given the water in the latter, and the high operating temperature, considerable oxygen and carbon dioxide were expelled. They were removed from the vessel by venting steam to the non-deaerating type open feedwater heater operated at 160 to 180 F. By doing so the vented gases were brought into intimate contact with relatively cold water and some were dissolved. Large quantities of gas, especially carbon dioxide, were

Fig. 14—Resumé of published data relative to solubility of CO_2 in pure water at a partial pressure of one atmosphere



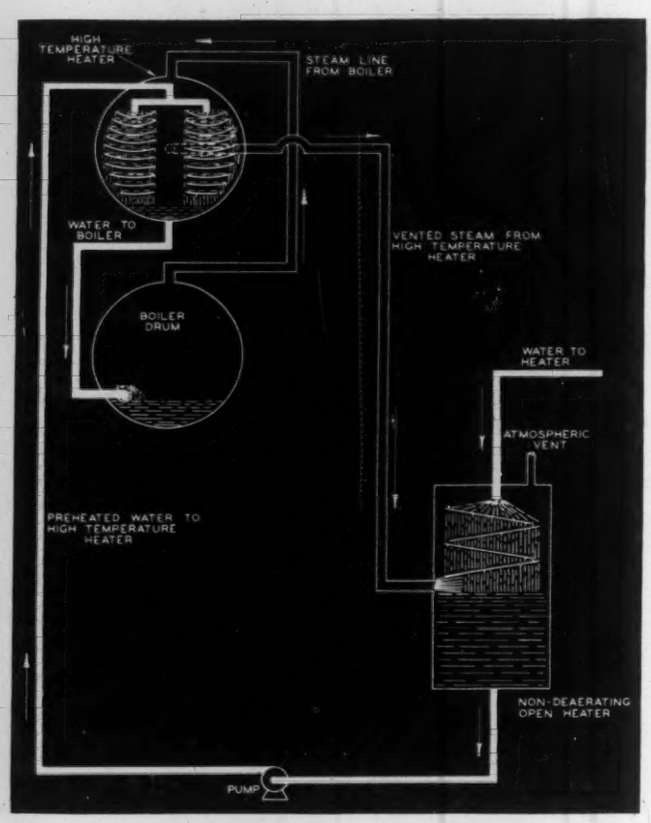


Fig. 15—Diagrammatic sketch of an "accumulating" feedwater cycle

found to be present in this cycle. At times as much as 1500 ppm of CO_2 was dissolved in the water leaving the low-temperature heater.

The Problem of CO_2 Elimination

In controlling the CO_2 content of steams derived from carbonate bearing feedwater, there are two possibilities to be considered: (a) removal from the feedwater, as a "pre-boiler" operation; (b) removal from the steam, as a "post-boiler" process. Only the first possibility has been given consideration in our studies.

In the treatment of feedwaters there are also two possibilities worthy of consideration: (a) destruction of the carbonate bearing salts and the expulsion of the liberated CO_2 from the water; (b) treatment of the water to prevent hydrolysis of carbonates within steam boilers. Here again the former consideration has been given the greater amount of study.

In destroying carbonate salts with the liberation of CO_2, as a "pre-boiler" operation, there are two expedients to be considered: (a) the use of an acid; (b) employing thermal hydrolysis. Both possibilities have been studied.

In setting up the proper expedients to be used for CO_2 removal, considerable thought must be given to the local conditions which obtain at the boiler plant in question.

Most boiler plants can be classified within one of the following categories:

1) Those in which only returned condensate is used as the source of boiler feedwater.

2) Those in which the boilers operate at pressures below an approximate value of 5 lb ga and in which the bicarbonate hardness of the feedwater is less than about 50 ppm.

3) Those in which the boilers operate at pressures higher than 5 to 10 lb ga and wherein a carbonate bearing water constitutes most of the boiler input.

In the case of plants in class 1, there is little likelihood of scale formations; thus there is little need for adding chemicals to prevent such an occurrence. The returned condensate, as a normal condition, will contain only a few ppm of CO_2. By passing the feedwater through an efficient deaerator to remove the oxygen inevitably present, an acceptable feedwater will usually result.

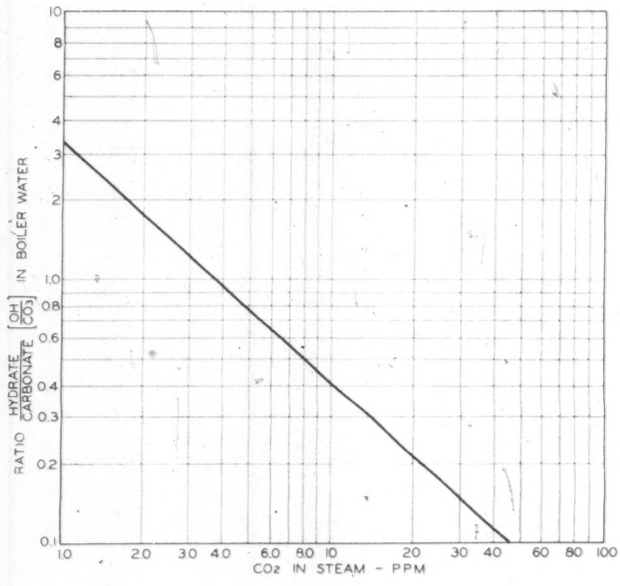
Similarly, for plants in class 2, scale formations are of little concern. In such cases, if the feedwater contains less than about 50 ppm of bicarbonate hardness, the CO_2 liberated by hydrolysis of the alkaline earth bicarbonates can be sequestered by adding calcium hydroxide to the boiler.

Tests conducted by Speller and Kylander[9] in a small boiler indicate that by this expedient the CO_2 entrained with steam can be controlled. The amount of calcium hydrate which must be added depends upon the amount of CO_2 introduced with the feedwater, and the OH-CO_3 relationship in the boiler water. In Fig. 16 is shown the equilibrium between the hydrate-carbonate ratio in the boiler water and the CO_2 in the steam, which the original investigators state obtains at about 5 lb pressure.

For plants in class 3, the production of a steam containing 2 ppm or less of CO_2 is fraught with many complexities; especially is this so for the higher operating pressures. At such stations the necessity for scale prevention is paramount and it is desirable that "sludge" formations be kept to a minimum. In order that utilization engineers as well as those concerned with boiler operation may appreciate some of the complexities involved, and that some of the inherent limitations of apparently obvious methods of removal may be made known, the results of a number of laboratory and plant

[9] F. N. Speller and R. R. Kylander, *Journal*, American Society of Heating and Ventilating Engineers, February and April, 1928.

Fig. 16—Relation of hydrate/carbonate content in "hard" boiler water and CO_2 in steam at operating pressure of about 5 lb ga. All analytical values are in ppm [parts per million] by weight



studies are given. These center around the possibilities of removing CO_2 from sodium bicarbonate solutions.

Removal of CO_2 from Sodium Bicarbonate Solutions

Any "temporarily" hard water that has passed through an efficient sodium zeolite softener is essentially a dilute sodium bicarbonate solution. As such it is definitely alkaline. To prevent undue corrosion in the boiler plant it is imperative the feedwater remain alkaline. Thus the problem of CO_2 removal narrows down to the development of methods for destroying the bicarbonate ion with the liberation of free CO_2 and the removal of this gas from neutral or weakly alkaline solutions.

Destruction of the Bicarbonate Ion—Obviously the bicarbonate ion can be destroyed by adding an acid. The reactions involved are so simple as to warrant no discussion here.

It is a generally accepted belief that for any carbonate solution to be at equilibrium it must be in contact with a gas phase containing a definite partial pressure of carbon dioxide. The obvious corollary would be that to reduce the CO_2 content of such a solution, CO_2-free steam, or air, might be bubbled through it. The theory, however, does not disclose the time required to reach the desired end point. For such a process to be practical it should be rapid—preferably almost instantaneous.

Removal of CO_2 from Aqueous Solutions—The theories bearing upon the removal of gas from solutions which react chemically with the gas are too involved for discussion here. Judging from the work of Baylis[10] it appears the release of gases from other solutions is influenced principally by the thickness of the liquid film at the water-gas interface, the rate of release being highest when the film is thinnest. He postulates that when a drop is first formed the liquid film has a thickness of only one molecule, that it builds up to about 0.00026 cm as the drop falls, and finally averages about 0.17 cm for water at rest.

This indicates that to achieve maximum removal the water should be subdivided as much as possible. A spray represents the most practical method for doing this and the results obtained should correspond with the characteristics of the spray nozzle used.

[*To be continued*]

[10] J. R. Baylis, *Water Works and Sewerage*, June, 1932.

Annual Air Conditioning Review

ON THE next page are tabulated comparative data on the number of installations and connected horsepower for air conditioning commercial buildings, industrial plants, and residences for the full year of 1938 and the first 11 months of 1939, with totals as of December 1, 1939. Institutional buildings and apartments are included with the commercial jobs. These figures were obtained from the utility companies serving the various areas covered, and the courtesy of the utilities in making the data available is gratefully acknowledged.

If these figures for those cities for which the necessary data are available are totalled, it will be found that the number of air conditioning installations during the first 11 months of last year was greater than in 1938, and the horsepower was slightly less.

Data such as are given in the table on the following page are difficult to compile with absolute accuracy, and cannot be obtained for as many cities as would be desirable. The information can be had only from electric utilities, and therefore (in many cases) the figures given do not cover installations which are not served by the utility—such as many industrial jobs, and jobs using other forms of refrigeration or latent heat removal than electric motor driven. Thus, horsepower figures do not fully reflect the installed air conditioning capacities. While the scope and form of the reported data vary for each reporting utility, the comparison between 1938 and 1939 for any one city is felt to be accurate, for both sets of figures were obtained from the same source.

According to Department of Commerce figures on the value of orders booked by 125 manufacturers of summer, winter and year 'round air conditioning equipment, air washers, filters and humidifiers, the first 10 months of 1939 were 57 per cent ahead of 1938. The fan group showed a 20 per cent increase, and if the two are combined the increase was around 45 per cent (first 10 months of 1939 compared to same period of 1938).

There seems to be general agreement that 1940 installations will exceed those made in 1939 by substantial amounts. Commercial jobs—stores, restaurants and offices, particularly—are expected to be especially active.

An important 1939 development pertaining to gas-using air conditioning equipment was the report of the American Gas Association's committee on industrial and commercial air conditioning. Theme of the report was that "existing marketing methods have failed to produce a significant sale of gas-using summer air conditioning equipment". The business done by the entire air conditioning industry is possible primarily because manufacturers obtain distribution through at least 1500 retail engineering-contracting concerns throughout the country, according to the report. If the gas industry is to obtain its share, it must either develop a distribution organization capable of competing with that mentioned, or see that gas products are placed in the hands of existing engineering-contracting organizations for sale by them. The committee recommended that the gas industry "make every effort to utilize the existing marketing facilities."

As to railroads, the Association of American Railroads reports that as of July 1, 1939, there were 11,351 air conditioned passenger cars in service, of which 6327 were railroad owned and 5024 were Pullman cars. The figure is lower than the total of 11,676 as of December 31, 1938, given in the May, 1939, HPAC because the latter figure was not confined to Class I U. S. roads, but included all U. S. and Canadian roads.

The American Ice Co. reports the following ice-using air conditioning installations for New York City, Washington, Baltimore, Philadelphia and Boston: 1938—30 installations, 936 tons refrigerating effect; 1939—34 installations, 1750 tons; total as of December 1, 1939—135 installations, 5890 tons.

Annual Air Conditioning Review (see preceding page)

Name of City or Territory and Approximate Population	1938								1939 (11 months)								Totals as of December 1, 1939							
	Residential		Commercial		Industrial		Total		Residential		Commercial		Industrial		Total		Residential		Commercial		Industrial		Total	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Ala.—Practically entire state, served directly or indirectly by Alabama Power Co. (1,003,800)	14	27.49	78	784.92	1	15	93	827.41	14	30.78	98	1780.11	2	788	114	2598.89	82	233.47	405	9925.52	19	1157.25	506	11316.24
Ariz.—Phoenix (88,000)*	70	244	12	282			82	526	30	61	16	237			46	298	163	560	84	5518	5	313	252	6391
Calif.—San Diego (160,000)			1	11	1	45	2	56			3	8.03			3	8.03			8	275.03	3	225.25	11	500.28
Colo.—Pueblo (50,000)			9	34.5			9	34.5	8	2	50	65.25			58	67.25	8	2	88	315.25	1	7	97	324.25
Conn.—Hartford (168,000)	3	15.75	16	111.75			19	127.5			21	346.75			21	346.75	7	22.5	100	1973.25	3	135	110	2130.75
D. C.—Washington (800,000)*	54	486.75	203	5028.75	6	307	263	5822.5	6	10.75	197	4969	1	2.25	204	4982	194	713.75	979	55451.25	16	533.25	1189	56698.25
Ga.—Savannah (100,000)	1	3.25	15	303.41			16	306.66	8	22.83	18	226.45			26	249.28	15	49.08	54	1075.11			69	1124.19
Ill.—Chicago (does not include suburbs) (3,500,000)	110	111	558	4824	9	195	677	5130	269	181	881	4419	20	457	1170	5057	555	569	3043	69878	168	10280	3766	80727
Ill.—Rockford (85,000)	10	7.25	23	101.5			33	108.75	3	6.25	18	91.5			21	97.75	45	51.15	80	861.28			125	912.43
Ind.—Indianapolis & Marion Counties (400,000)	11	12.84	53	632.17	3	66.5	67	711.51	17	32.4	48	337.69	5	37.5	70	407.59	96	159.24	304	6316.06	17	638.5	417	7113.8
Iowa—Des Moines (150,000)	14	17.82	51	417.94			65	435.76	9	6.73	83	2058.36			92	2065.09	75	107.11	329	7521.66	5	42.6	409	7671.37
Iowa—Sioux City (90,000)	4	4.5	15	133.75			19	138.25	2	1.75	34	108.75	2	8.75	38	119.25	34	48.83	135	1962.33	2	8.75	171	2019.91
Kans.—Lawrence (80,000)	4	2.75	13	140			17	142.75	1	1	17	61.5			18	62.5	17	30.25	81	772.5			98	802.75
Ky.—Louisville (350,000)	3	11	51	452.13	5	14	59	477.13	16	16.33	63	513.21	15	135.55	94	665.09	NR	NR	NR	NR	NR	NR	367	5212.17
La.—New Orleans (471,000)	NR	NR	NR	NR	NR	NR	NR	NR	51	84	78	2485	5	41	134	2610	NR	NR	NR	NR	NR	NR	NR	NR
Mass.—Boston Edison Co. territory (1,400,000)	3	10	352	1662	8	60	363	1732			53	1639	6	124	59	1763	48	111	811	14436	39	1941	898	16488
Md.—Baltimore area (1,160,000)	80	101	152	2941	3	55	235	3097	164	135.5	268	2284.5	2	33	434	2453	356	408	835	17419	22	833	1213	18660
Md.—Potomac Edison System*	7	5	27	130	1	20	35	155	5	4.5	36	93.3	5	8.5	46	106.3	NR	NR	NR	NR	NR	NR	172	622.8
Maine—Central part	1	20.5	5	28			6	28.5			17	84.5			17	84.5	1	0.5	26	130.5			27	131
Mich.—Detroit and vicinity (Territory of The Detroit Edison Co.) (2,581,000)*	36	59	163	3078	8	475	207	3612	62	59	265	3106	11	253	338	3418	378	499	953	28934	54	3245	1385	32678
Mich.—Lansing (90,000)*	1	0.25	7	74.5			8	75			2	105			2	105	3	6.5	16	315			19	321.5
Minn.—St. Paul and suburban area (300,000)*	8	22	44	305	2	6	54	333	2	11	63	515	1	9	66	535	63	121	264	2759	4	18	331	2898
Mo.—Kansas City (413,000)	60	116	121	1310.84	3	43.1	184	1469.84	105	107.67	136	1721.77	5	102	246	1931.44	500	938.67	748	16930.16	18	386	1266	18254.83
Mo.—St. Joseph (86,000)	33	49.25	71	1343.24	4	136.5	108	1528.99	5	3.75	17	60.93	1	6.5	23	71.18	38	53	88	1404.17	5	143	131	1600.17
Mo.—St. Louis (1,250,000)	231	303.41	256	3481.95	5	71.84	492	3857.2	378	367.7	377	7649.56	11	492.26	766	8509.52	1263	1961.48	1491	40841.25	79	3293.99	2833	46096.72
N. H.—Manchester Territory*	2(S)	1.34	19	92.85	2	7.5	78	114.79	1(S)	1	12	206.75	0	0	79	238.42	4(S)	3.84	42	412.3	6	34.25	205	504.91
	55	13.10							66	30.67							153	54.52						
	(W)								(W)								(W)							
N. Y.—Central N. Y. Power Corp. (821,000)*	21	24.5	156	2813.63	25	1456.7	202	4294.83			51	281.3			51	281.3	21	24.5	207	3094.93	25	1456.7	253	4576.13
N. Y.—New York (Manhattan, Brooklyn, Bronx, Queens) (6,700,000)	121	124.78	767	19473.37	13	688.94	901	20287.09	165	152.71	1212	15930.12	27	718.98	1404	16801.81	NR	NR	NR	NR	NR	NR	NR	NR
N. Y.—Rochester (469,000)	2	4.75	27	296	4	21.25	33	322	4	7.25	35	246.25	3	105	42	358.5	36	65	145	4262	22	25621	203	29948
N. Y.—Westchester County (500,000)	24	45	31	245.5			55	290.5	23	17.9	55	583.5	8	69.5	86	670.9	88	138.15	162	4679.45	13	255	263	5072.6
Ohio—Akron (413,000)	1	1.5	7	119.5			8	121			8	193.33			8	193.33	8	10.75	75	1650			83	1660.75
Ohio—Cincinnati (460,000)	48	43.75	92	1033.83			140	1077.58	71	65.97	153	1333.69			224	1399.66	NR	NR	NR	NR	NR	NR	NR	NR
Ohio—Dayton and surrounding small towns (375,000)	21	18	29	595	1	55	51	668	19	23.08	45	289.31	1	9.5	65	321.89	91	127.4	169	3399.25	45	1008.5	305	4535.15
Ohio—Toledo (300,000)*	11	15	31	204	2	20	44	239	NR	NR	30	897	1	60	31	957	35	73	160	4039	19	692	214	4804
Okla.—Oklahoma City, Okla. G and E. Co. (661,000)	75	185	102	1765			177	1950	70	101.21	84	749.74	6	9.17	160	860.12	367	742.88	439	8267.87	20	115.12	826	9125.87
Pa.—Lawrence, Mercer, and part of Butler, Beaver and Allegheny counties (216,676)			10	139.5			10	139.5			7	33.5	1	3	8	36.5	3	1.5	25	231.5	4	6	32	239
Pa.—Philadelphia area (2,754,000)	78	120.4	207	6480.8	7	1366.5	292	7967.7	64	62.66	232	4737.97	14	1319.5	310	6120.13	287	433.66	1027	39050.07	131	9426.1	1445	48909.83
Pa.—Pittsburgh (1,400,000)	34	26.25	172	1329.25	5	51.25	211	1406.75	29	21.5	150	951.75	2	11.25	181	984.5	170	194.75	713	13522.25	24	743.5	907	14460.5
R. I.—Providence and Southern Rhode Island (470,000)	3	8.25	12	168	2	3.25	17	179.5	1	0.75	31	425.62	3	11	35	437.37	10	25.25	97	2103.51	8	20.07	115	2148.83
S. C.—Columbia (70,000)			8	83.25			8	83.25	2	6	11	205.75			13	211.75	2	6	39	1253.75			41	1259.75
Tenn.—Chattanooga (150,000)	3	3.75	6	86			9	89.75	4	5	13	395	1	15	18	415	NR	NR	NR	NR	NR	NR	NR	NR
Texas—El Paso (130,000)*	1322	336	9	590	1	5.5	1332	931.5	1708	683	309	175	20	8	2037	866	3488	1157	761	1773	31	90.5	4280	3020.5
Texas—San Antonio (232,000)	21	76	30	1408.75	2	4	53	1488.75	19	60.67	28	398			47	458.67	87	226.5	183	10423.5	2	4	272	10654
Va.—Lynchburg and vicinity (50,000)	1	1	7	27.5	1	1.5	9	30	5	5	5	3	1	1	11	9	6	6	12	30.5	2	2.5	20	39
Va.—Richmond district (390,000)	6	7	45	832	1	260	52	1099	3	1.1	83	1365.4	3	495	89	1861.5	41	68.1	235	6279.4	16	1405	292	7752.5
Va.—Va. P. S. Co. (448,500)			27	239.6			27	239.6			23	222.8			23	222.8			130	1134.52			130	1134.52
Wash.—Spokane and vicinity (285,000)			24	98	4	56	28	154			16	75	1	67	17	142			71	877	101	2073	172	2950
W. Va.—Wheeling (80,000)			37	1000.54	6	262	43	1262.54			8	46.25	1	19.25	9	65.5			45	1046.79	7	281.25	52	1328.04

*See footnote below. "NR" means no record.

Ariz.—Phoenix: There are approximately 15,000 evaporative coolers, representing an estimated 2300 hp in addition to installations tabulated.

D. C.—Washington: Commercial installations include government buildings.

Md.—Essentially a rural area covering 6000 sq mi and including western Md., panhandle of W. Va., northern Va. and southern Pa.

Mich.—Detroit: For years prior to 1937, installations other than central station electric are included and the hp is compressor hp only for those years. There were also 241 self contained conditioners totaling 338 hp in 1938 and 286 conditioners totaling 453 hp in 1939.

Mich.—Lansing: Well water at 50 F available which reaches downtown district at 55 F during summer months.

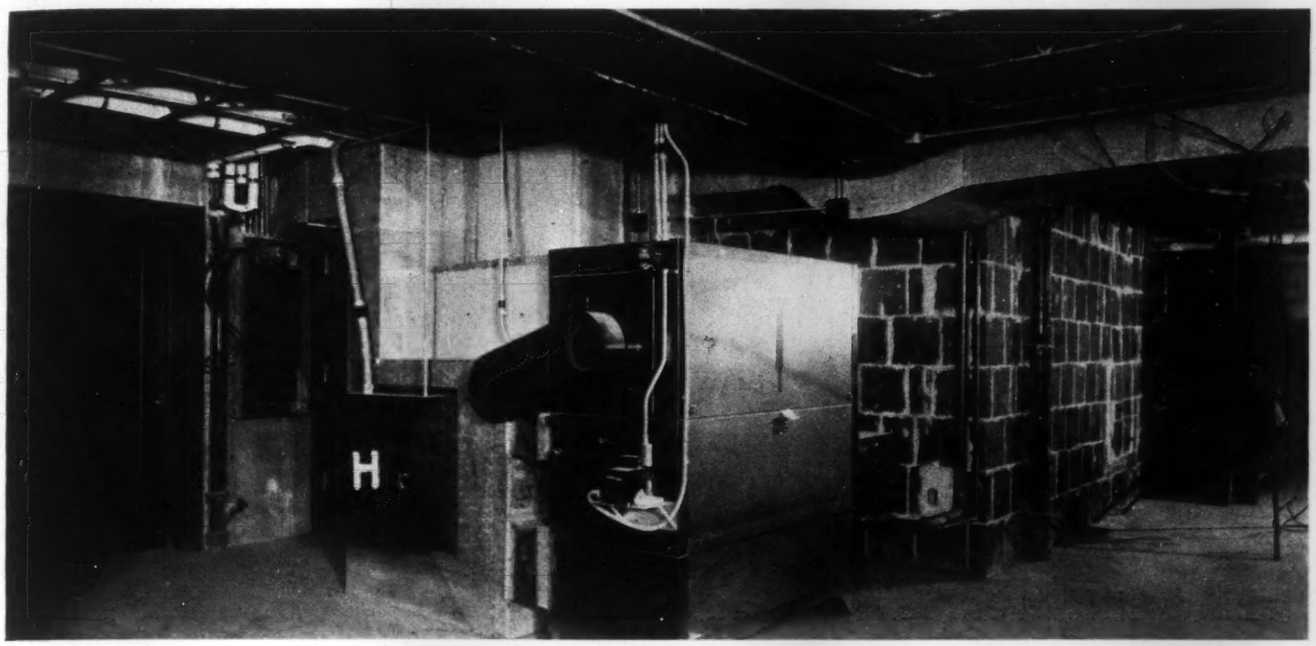
Minn.—St. Paul: 2650 tons of well water cooling installed to date.

N. H.—"S" means summer and "W" means winter installations.

N. Y.—Includes Syracuse, Oneida, Rome, Utica, Herkimer, Watertown, Ogdensburg, Malone, Potsdam, Oswego, Fulton and Cortland.

Ohio—Toledo: Totals for 1939 and as of December 1, 1939, do not include residential installations.

Tex.—El Paso: Approximate capacity in tons of installations not having motor driven refrigeration is 17500, based on average of 5 tons sensible cooling effect for each home type evaporative cooler. Several commercial installations consist of coils using water cooled by evaporation.



The equipment serving the auditorium in the Appalachian Electric Power Co.'s building. The electric heater is inserted in the air chamber (*H*)

Electric Elements Well Adapted to the Air Conditioning Heating Cycle

By Lee P. Hynes*

AN air conditioning system must often be zoned to supply heating or cooling as needed in each area of a building. Control is very important and must principally be accomplished by varying automatically the volume or the temperature of the air circulated; this is complicated by the fact that the required air volume for the cooling cycle is often different from that for the heating cycle.

For the simplest form of heating system serving only one room, adequate regulation can often be obtained by controlling the temperature of the air supply from a thermostat on the wall of the room or in the return air duct. However, if the room is large and subject to variable conditions, it is often desirable to control the temperature locally at opposite sides or ends of the room; this can be done by automatically varying the volume of air delivered by the different air outlets in the room, or by automatically varying the temperature of this air. In either case the control must be actuated from thermostats at critical points in the room, exposed to the different local conditions.

In larger buildings, it is generally difficult to design the system so that each room has the individual local temperature regulation essential to satisfactory performance. Consequently, some compromise is usually made which will meet fairly well average conditions. A common practice is to design the system on the basis of an air supply temperature suitable for the room having the least exposure. Approximate heat balance is then obtained by damper adjustments to give the volume of air required at this temperature which must be delivered to each room to meet average operating conditions.

To balance the heating system completely requires the application of local heat in each room to compensate for variations in exposure. Where local heating is used it is, of course, necessary to control it in each room by local thermostats. Electric heating has many advantages for this service.

Electric heat is often used for the entire heating cycle, but where steam is available and is preferred for the base heating load, it can be used in the main heaters near the fan to maintain the air supply at design temperature. Electric heaters can then be used as boosters in local branch air supply ducts and behind the air outlet grilles in each room. This simplifies the job, for it is easy to run circuit wires to each location. With electric heat the control is also simplified because only circuit wires and relays are required.

Building Heated by Electricity

A good example of a modern air conditioning system having an all-electric heating cycle is the office building of the Appalachian Electric Power Co., Beckley, W. Va. This attractive building houses the local business and

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engineering offices, a public lobby, merchandise display lobby, public auditorium, service work shop, storeroom, and a large garage for company cars and trucks. The entire building is heated electrically and, with the exception of the garage and storeroom, is thoroughly air conditioned.

Garage—The garage is heated by three electric unit heaters mounted on the ceiling with cone outlets arranged to discharge the heated air downward to the floor level where it spreads under the cars. One of these heaters is directly in front of the large entrance door to overcome the tendency to cold drafts along the floor. The other two heaters are in other portions of the room, each under the control of a local thermostat. In this way the garage heating is balanced regardless of variations in the local heat loss conditions.

Auditorium—Because the auditorium is not used continually, it is served by an individual system with a complete air conditioning unit in the basement. An electric heater is situated in a special fan intake chamber, through which the outdoor air supply and a portion of the return air pass on their way to the fan inlet. The electrical input of this heater is varied according to the demand for heat by means of an automatic selector control so that just enough energy is used to maintain the air supply at the desired temperature. As this system serves only the auditorium, booster heaters are not required and adequate temperature control is secured by means of a thermostat in the return air duct which actuates the selective energy input controller.

Lobbies and Offices—The main part of the building comprises the entrance and display lobbies, and 14 business and engineering offices. It is served by a second system having an air conditioner in the basement. The main electric heater is in a special fan intake chamber through which the outdoor air supply and a portion of the return air pass on their way to the fan inlet. This heater is controlled by a thermostat mounted on the wall of a small interior service room having no outdoor wall area; this thermostat actuates a selective control which governs the energy input to the heater and constantly maintains the desired air supply temperature.

In addition to this electric base heating load, there are 18 electric booster heaters in branch air supply ducts and behind air outlet grilles in the various rooms. These are controlled by local thermostats and serve automatically to balance the heat distribution. They also permit the maintenance of different temperatures in different rooms in accord with the wishes of the occupants, and compensate for changes in heat loss due to varying weather conditions, making the temperature control of the entire system completely and locally automatic.

The complete zoning of this building with local thermostatic control throughout prevents waste of heat because no room is overheated beyond the wishes of its occupants. As a further economy, a special night control is operated from an electric clock switch having a seven day program dial. At night, on holidays, and over week-ends, a lower temperature is maintained than during regular office hours, with considerable economy of heating energy.

An electric heating system for a building of this kind requires a careful electrical circuit layout. The heaters should be balanced under all operating conditions on the available polyphase power circuits. The various automatic control panels should be situated at convenient points so as to simplify installation of the electrical conduit and circuit wires.

Electric heating has a number of advantages for the heating cycle of air conditioning systems, particularly in connection with controlling the conditions maintained in various rooms. Where steam is preferred for handling the base heating load, electric heaters may be used as boosters in local branch supply ducts and behind the air outlet grilles. . . . An all-electric installation is briefly described here. The author also explains a basic difference between heating with steam and with electricity, and how it affects control

Difference Between Electric and Steam Heat

The application of electric heat to an air conditioning system varies considerably from steam heating practice. With steam the standard method of controlling the heat input is by means of a bypass damper operated by a thermostat mounted in the return air duct or on the wall of a room. This bypass damper is automatically adjusted according to the need for heat. When less heat is required, a larger percentage of the air is bypassed around the heater, which changes the steam condensation rate of the heater and reduces correspondingly the heat input to the system.

This method cannot be used for electric heating because of a basic difference between the transfer of heat from an electric heater and from a steam heater. Steam has approximately a constant temperature for any given pressure and if less air is passed over the heating coils, the condensation rate is reduced but there is no appreciable increase in the surface temperature of the steam coils. The result of reduced air flow is reduced heat input.

Electric heat works in a different manner. If the volume of air flowing over electric heating elements is reduced without any change being made in the electrical power supply, there will be no reduction in the total heat input. As the air volume is reduced, the temperature of the electric heater surfaces will rise until the air can be forced to absorb all of the heat being given off. Consequently, it is necessary to control the actual input of electrical energy to the heating elements. This can be done in a number of ways, but a proper design is essential for safe and satisfactory operation.

It is also necessary properly to interlock the power supply for the heaters with the fan motor starter so that no power can be on the heating system unless the fan is running. A maximum temperature safety trip is also required in the heater chamber so that any improper reduction in air flow or interference with the normal control functions will immediately trip off the power supply before a harmful rise of temperature occurs in the heater chamber.

Piping Problems Are Considered at Annual Meeting of the ASME

A very brief review of three of the papers on piping presented at the annual meeting of the American Society of Mechanical Engineers is given here. . . . They include discussions on stress in pipe lines due to the combined effects of pressure and expansion, three dimensional bends, and heat transfer to falling water films

AMONG the papers presented at the annual meeting of the American Society of Mechanical Engineers at Philadelphia last month were three on problems involved in piping design. These are reviewed very briefly in the following paragraphs. The complete papers will of course be available in publications of the ASME.

The significance of, and suggested limits for, the stress in pipe lines due to the combined effects of pressure and expansion were discussed by D. B. Rossheim[1] and A. R. C. Markl.[2] The paper was prepared as a vehicle for discussion of the following basic problems, on which agreement is necessary to establish a satisfactory working stress basis for pipe lines:

1) Proper allowable stresses for combined pressure and expansion effects.

2) Influence of and limits for localized stresses under static and repeated loading.

3) Capacity of bolted joints to withstand expansion effects without leakage or damage to flanges, bolts or gaskets.

4) Effect of prespringing, self springing, creep and yielding on operating and off-stream stresses.

The authors attempted in the paper to point out various aspects of each issue, rather than to limit the discussion to their own personal views. Following the presentation of the reasoning and data affecting the problem of pipe lines under expansion—which is quite complex—they gave the following basic assumptions for use in evaluating stresses and limits for the combined stresses resulting from pressure and expansion:

Evaluation of Expansion Thrusts and Stresses—The calculation of the line for expansion serves the purpose of establishing the range over which stresses vary rather than the maxima and minima, and accordingly consideration of the amount of prespringing required can be deferred to the end of the calculation. Since the relaxation stress definitely limits the hot condition, both prespringing and self springing will tend to make the room temperature condition the controlling one and calculations accordingly should be based on the elasticity modulus at room temperature rather than the reduced value in operation. Where a close estimate of thrusts in operation is desired, a simple conversion by the ratio of the hot to the cold elasticity moduli will give the required results.

Simple Stresses to Be Considered—In arriving at the principal stresses, consideration should be given in all problems to the following stresses at the outside surface of the pipe:

Simple pressure stresses:
- Circumferential
- Longitudinal

Line expansion stresses:
- Longitudinal bending (two planes)
- Torsion

Local stresses:
- Longitudinal bending in curved pipe and creased ells
- Longitudinal bending in corrugated pipe

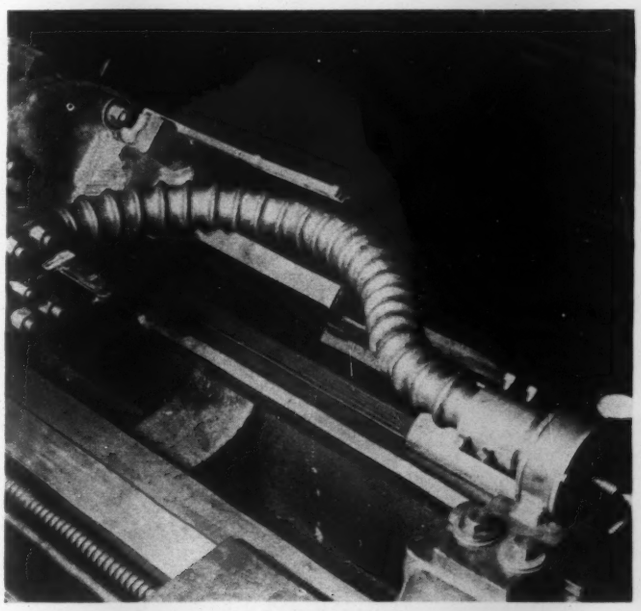
The radial pressure stress is zero at the outer surface. Direct stress due to the axial force and shearing stresses caused by transverse forces need be calculated only where the piping is extremely stiff. The local stresses are evaluated conveniently by using stress intensification factors which are discussed later. We believe that the circumferential bending stress (curved pipe) and other local stress raisers, such as branch connections, may be neglected, although the use of unreinforced openings and reinforcement details should be more closely controlled where service conditions involve distinctly cyclic loading. Bolted joints will be commented on as a separate item.

Stress Intensification Factors: Fatigue—In addition to the ordinary usage of the term "stress intensification factor," it will here also be applied as a correction factor reducing the elastic range of stresses where cyclic loading is involved. The values given in Table 1 are suggested as a working basis.

Table 1—Suggested Stress Intensification Factors

Shape	Stress Intensification Factor: Noncyclic Stresses	Stress Intensification Factor: Cyclic Stresses
Plain tangents	1	1
Plain bends and creased bends	β	k
Corrugated tangents and bends	2½	5

Cyclic stresses would be considered to obtain where service conditions involve pulsating loads or frequent temperature



Corrugated offset quarter bend mounted in a lathe for gaging stress and deflection prior to fatigue test

[1]Mechanical Engineer, M. W. Kellogg Co.
[2]Assistant Mechanical Engineer, M. W. Kellogg Co.

changes; a closer definition should be considered, although it cannot be expected to relieve the designer entirely from a consideration of the merits of each case.

The factors for plain tangents require no comment. In the case of plain bends, k and β are the familiar Kármán or flexibility factor and Hovgaard's longitudinal stress intensification factor, respectively. Both are applied to flexure stresses in the plane of the bend only. Creased bends are realized to occupy an intermediate position between plain and corrugated pipe, but are usually classed with the former in the absence of reliable data. For straight and curved corrugated pipe, stress calculations are based on the moment of inertia of the pipe before corrugating, and the stress intensification factor is applied to the longitudinal pressure stresses and the bending stresses. It is realized that the moment transverse to the plane of a bend can vary from pure bending to pure torsion with an intermediate range where both effects are present, and that the true state of stress is not evaluated by present methods; however, this and kindred problems can be considered as future refinements as our knowledge of this subject expands.

For noncyclic stresses, we have used the endurance properties of 20,000 cycles as a rough guide; for cyclic loading, 500,000 stress reversals have been considered as fairly representative of the endurance limit.

Combination of Stresses—If failure is associated with yielding, the Hencky-Mises theory most accurately predicts the elastic limit under combined stresses, although the maximum shear theory offers sufficiently close results and is somewhat easier to apply. On the other hand, present-day safety factors for pressure stress are predicated on the principal stresses (Rankine theory), and since local yielding results in stress redistribution with no loss in utility, average stresses are probably the best overall strength index. For the present, we would favor the continued use of the principal stress theory for calculations based on the elastic theory. Where stresses under steady creep are being considered, the maximum shear theory may be used.

Suggested Stress Limits—Using as a basis the allowable stress established in the codes for calculating pipe wall thickness under pressure, the following limits for the available stress range are suggested:

For no prespring

$$\text{Allowable stress range} = 0.75\ (S_A + S_A') \quad [6]$$

and for 50 per cent prespring

$$\text{Allowable stress range} = S_A + S_A' \quad [7]$$

where S_A = allowable stress at room temperature and S_A' = allowable stress at operating temperature, both to be introduced with their algebraic values so that they will always be numerically additive.

As an illustration, the allowable ranges obtained for combined pressure and expansion stresses in accordance with formulas [6] and [7] are listed in Table 2 for various line temperatures, as based on allowable pressure stresses for seamless low carbon steel piping (48,000 lb per sq in. minimum ultimate tensile strength) to ASTM specification A-106 as proposed for the ASA code for pressure piping.

Table 2—Allowable Ranges for Combined Pressure and Expansion Stresses as Obtained with Formulas [6] and [7]

Line temperature, F	Allowable stress range: Oil piping section, No prespring	Oil piping section, 50% prespring	Power piping section, No prespring	Power piping section, 50% prespring
Up to 650	18000	24000	14400	19200
700	17663	23550	14100	18840
750	17175	22900	13740	18300
800	16500	22000	13200	17600
850	15413	20550	12330	16440
900	14250	19000	11400	15200
950	12563	16750	10050	13400
1000	10875	14500	8700	11600

For any intermediate degree of prespring, the relation

$$\text{Allowable stress range} = (0.75 + s/2)\ (S_A + S_A') \quad [8]$$

could be used, where s = percentage of prespring expressed as a fraction = 0.50 maximum.

A higher degree of prespring than 50 per cent is beneficial at elevated temperatures in establishing the piping nearer equilibrium thus reducing the amount of permanent set necessary to bring stresses to the relaxation limit. However, this will not affect long time conditions, and is therefore not considered to warrant an increase in the elastic range.

Investigation of Bolted Flanged Joints—The rules suggested in the preceding apply to pipe and do not consider joints. These are properly investigated after the completion of the line calculations. We have already indicated that ASA standard flanges are probably sufficiently strong to take any bending stresses ordinarily encountered and, at least with ring type gaskets, possess a fair resistance to torsion. In doubtful cases, and where special flanges are used, an investigation will be indicated. The ASA flanges should probably be explored more thoroughly, and definite limits imposed on the allowable bending and torsion moments depending on the type of gasket used.

Appendices to the paper presented the results of tests of plain, corrugated and creased bend pipe under cyclic variation of stress, and a discussion of the problem of bolted flanged connections.

Three Dimensional Pipe Bends

Stresses and deflections of three dimensional pipe bends was the subject of a paper presented by H. Poritsky[3] and H. D. Snively.[4] While many treatments of the subject of stresses of three dimensional pipe bends have appeared, and the calculation of these stresses and deflections is perfectly straightforward, it is still very complicated. The authors therefore presented an analogy in their paper which should be of assistance in simplifying these calculations by pointing out their similarity to familiar dynamical concepts involving products and moments of inertia and moments of momentum.

Heat Transfer to Water Films

A third ASME meeting paper of interest to HPAC readers was concerned with the heat transfer to falling water films; it was prepared by W. H. McAdams,[5] T. B. Drew[6] and G. S. Bays, Jr.[7]

Data were presented for heating water as it flows by gravity in turbulent motion down the inner walls of vertical copper pipes, ranging in height from 0.41 to 6.1 ft. Heat balances check within 5 per cent and the temperature of the inlet water ranges from 38 to 146 F. The data are adequately correlated by the equation: $h = 120\Gamma^{1/3}$, where Γ ranges from 600 to 15,000 lb of water per hr per ft of width of stream. Steam-side and over-all coefficients were given. The rather inadequate data for streamline flow by gravity over nearly horizontal pipes (trombones) were reviewed.

The symbols involved in the above equation were defined as follows:

D = diameter, ft; D_i for inside

h = individual coefficient between tube surface and water layer, Btu per hr per sq ft per deg F; based on logarithmic-mean temperature difference

w = water rate, lb per hr leaving the tube

Γ = water rate from tube per unit width of stream, lb per hr per ft; for vertical, $\Gamma = w/\pi D_i$

[3]Engineering General Dept., General Electric Co.
[4]Engineering General Dept., General Electric Co.
[5]Professor of Chemical Engineering, Massachusetts Institute of Technology.
[6]E. I. du Pont de Nemours & Co.
[7]Humble Oil & Refining Co.

SHOW SECTION

HEATING, PIPING AND AIR CONDITIONING

January, 1940

CLEVELAND PLAYS HOST

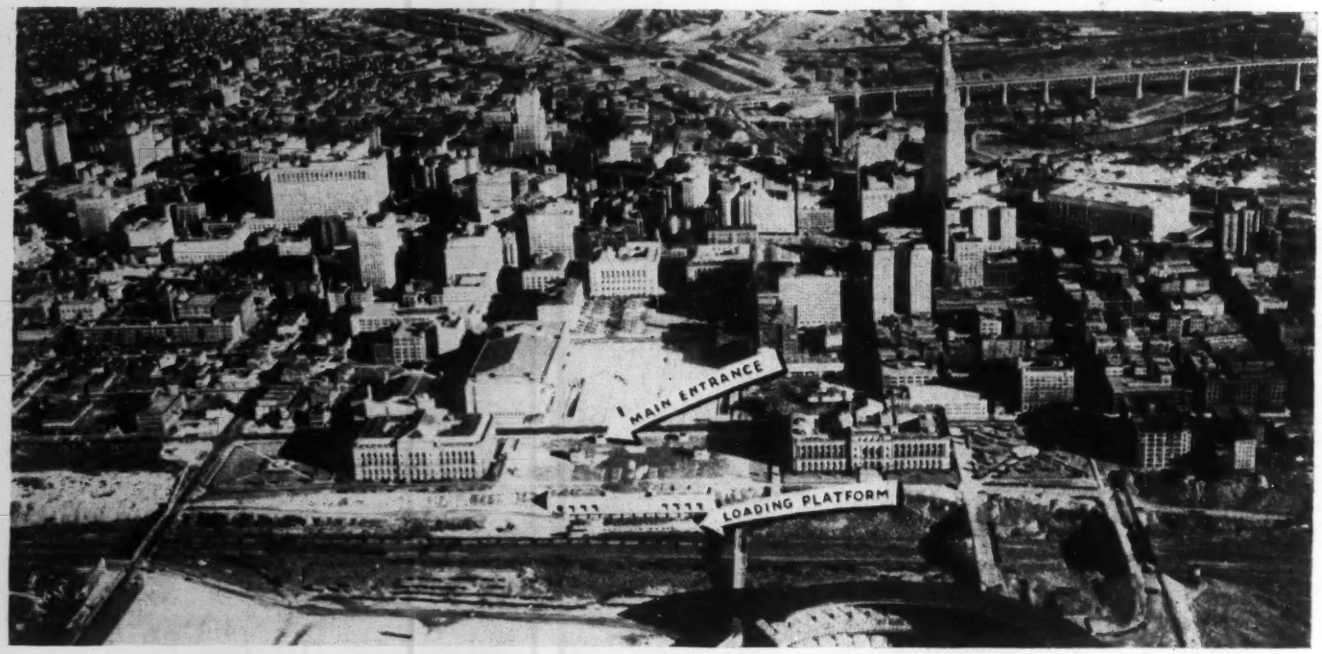
to

Sixth International Heating, Ventilating and Air Conditioning Exposition

46th Annual Meeting, American Society of Heating and Ventilating Engineers

44th Annual Convention, National Warm Air Heating and Air Conditioning Association

January 22-26



Lakeside Hall—where the Sixth International Heating, Ventilating and Air Conditioning Exposition will be held

Again the Industry Goes on Display

AIR conditioning, heating, ventilating, piping and affiliated equipment goes on display in its biennial show and members and guests of the American Society of Heating and Ventilating Engineers and the National Warm Air Heating and Air Conditioning Association review in technical and business sessions the industries' developments and accomplishments during the week of January 22 in Cleveland.

The occasion for it all is the Sixth International Heating and Ventilating Exposition, more familiarly known as "The Air Conditioning Exposition," the 46th annual meeting of the American Society of Heating and Ventilating Engineers and the 44th convention of the National Warm Air Heating and Air Conditioning Association. Headquarters for these three important affairs are Lakeside Hall, the Hotel Statler and the Hollenden Hotel respectively. Opportunity to explore, discuss, experience and meet the "What's What" and "Who's Who" of these great industries is obviously provided in unstinted measure by this combination of activities.

The "Show" opens at 2:00 p. m. on Monday, January 22, and runs daily thereafter through Friday, the 26th, from 12:00 noon to 10:30 p. m. More than 300 leading manufacturers have taken more space than at any previous exposition to present a wide variety of products for every kind of heating, ventilating and air conditioning application. The breadth and scope of the showings can be seen in the list of exhibitors with the brief summary of what they are displaying in the following pages.

The art of display . . . attractive, practical, easy to see and quick to understand . . . reaches a new high at each succeeding exposition. Here in Cleveland, the displays will go far beyond those of previous shows in the matter of "live exhibits" . . . equipment in actual operation. Executives and representatives of the exhibiting companies will be on hand to explain and answer questions.

The programs of the ASHVE and NWAHACA are given in following pages. Sessions have been planned to cover the subjects of vital importance to current and future practice and the man who would keep abreast of his field will make it a point to be at the Statler or Hollenden when those of particular interest to him are being presented. On Wednesday afternoon the two organizations will get together in joint session.

In addition to the technical sessions, the Cleveland committees of the two organizations have arranged for some very interesting inspection trips to nearby plants. One such trip is to the new continuous strip mill of Republic Steel Corp. housed in buildings covering 21 acres and located at the mouth of the Cuyahoga River. Permission has also been granted for one bus load of visitors to Industrial Rayon at Painesville . . . a completely windowless plant with 1900 tons of refrigeration for air conditioning and production processes. On the inspection trip list, too, are the research laboratory and equipment of Case School of Applied Science, the American Gas Association Laboratory and the Brewing Corp. of America . . . a group of trips that should meet the interests and desires of all visitors.

Throughout these days of seeing, hearing and talking the products, the theory, the practice and the problems of heating, ventilating and air conditioning are interspersed entertainment activities that will provide plenty of fun and contacts. On Monday night, after registra-

Night view of Cleveland overlooking the Cuyahoga River

tion and exposition activities during the day, the Northern Ohio chapter of the ASHVE will put on a get-together party and informal dance in the Euclid ballroom of the Statler. On Tuesday night, the Cleveland committee of the warm air group, with the aid of Northern Ohio manufacturers and jobbers, will provide a stag smoker and floor show in the grand ballroom of the Hollenden. On Wednesday night the ASHVE's annual banquet and dance will be held in the grand ballroom of the Statler. Members and guests of both organizations are invited to all these functions.

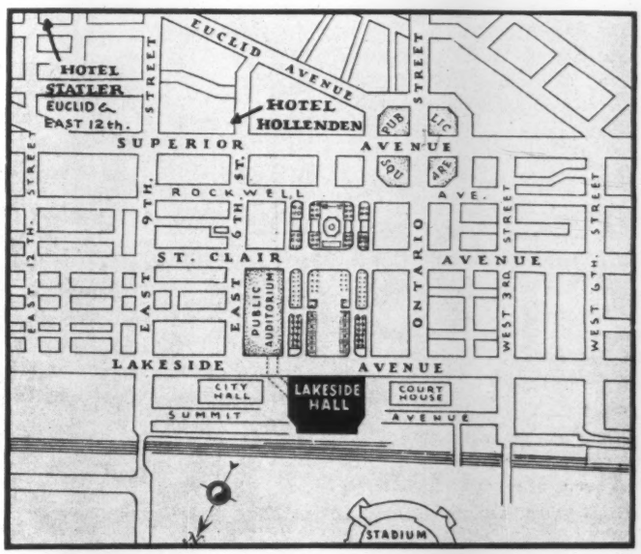
As for the ladies, there will be receptions, tours and parties throughout the week in addition to these evening affairs.

To the following committees goes credit for these arrangements: Northern Ohio chapter, ASHVE . . . Lester T. Avery, general chairman of arrangements; G. L. Tuve, honorary chairman; Philip Cohen and L. S. Ries, vice-chairmen; C. F. Eveleth, technical sessions; John Paul Jones, publicity; E. W. Gray, finance; C. A. McKeeman, inspection trips; D. L. Taze, attendance; F. A. Kitchen, banquet; A. L. Vanderhoof, transportation; H. E. Wetzell, entertainment; Paul Gayman, registration-reception; Mrs. W. R. Rhoton, ladies.

Cleveland National Warm Air Heating and Air Conditioning Association convention committee . . . Harold S. Sharp, general chairman; C. E. (Jim) Wilcox, entertainment; S. D. Yardley, plant inspections; R. A. Jack, publicity; George S. Auer, budget.

Headquarters, ASHVE

Exhibit hall and hotel locations



Headquarters, NWAHACA

Programs for the Meetings

American Society of Heating and Ventilating Engineers — Hotel Statler

46th Annual Meeting

Monday, January 22

8:30 a. m.—Registration—Hotel Statler (Mezzanine).
8:30 a. m.—Ladies Reception (Lattice Room—Mezzanine).
9:30 a. m.—Conference of Chapter Delegates (Pine Room).
10:00 a. m.—Council Meeting (Tavern Room).
10:30 a. m.—Committee Meetings.
2:00 p. m.—Opening of Sixth International Exposition—Lakeside Hall.
2:30 p. m.—Nominating Committee Meeting.
5:00 p. m.—Social Hour (Pine Room—Mezzanine).
8:00 p. m.—Committee on Research Meeting.
10:00 p. m.—Get-together Party (Informal Dance—$1.00 per man—Ladies free—Euclid Ballroom).

Tuesday, January 23

8:30 a. m.—Registration—Hotel Statler (Mezzanine).
9:30 a. m.—Technical Session—Hotel Statler (Grand Ballroom).
Greetings by Hon. Harold L. Burton, Mayor of Cleveland.
Response by Pres. J. F. McIntire.
Reports of Officers.
Report of Council Committees.
Technical Papers—
Effect of Lint on Air Filter Performance, by Frank B. Rowley and Richard C. Jordan.
Costs of Gas and Electric Powered Air Conditioning Plants, by G. E. May.
Dynamical and Thermal Behavior of Water Drops in Evaporative Cooling Processes, by H. B. Nottage and L. M. K. Boelter.
Report of Tellers of Election.
9:30 a. m.—Ladies Tour*—Cleveland Orchestra Rehearsal—Severance Hall.
12:00 noon—Ladies Luncheon — Crosby's Restaurant (East 105th and Carnegie).
12:00 noon—Heating and Ventilating Exposition—Lakeside Hall.
1:30 p. m.—Ladies Tour—Electrical Housekeeping Institute, Nela Park (Trip starts from Crosby's).
2:00 p. m.—Technical Session Hotel Statler (Grand Ballroom).
Solar Radiation and Heat Transfer Through Glass Block Construction, by F. C. Houghten, David Shore and Harold T. Olson.
Thermal Test Coefficients of Aluminum Insulation for Buildings, by G. B. Wilkes, F. G. Hechler and E. R. Queer.
Effect of Diminishing Return on the Value of Insulating Materials, by Paul D. Close.
Calculation of Coil Surface Areas for Air Cooling and Dehumidification, by J. W. McElgin and D. C. Wiley.
5:00 p. m.—Social Hour (Pine Room—Mezzanine).
6:30 p. m.—Past Presidents' Dinner.
8:00 p. m.—Informal Theater Parties.
10:00 p. m.—Stag Smoker—Hollenden Hotel (Grand Ballroom)—Sponsored by the National Warm Air Heating and Air Conditioning Association for their members and guests and those of the ASHVE. A colorful event after exposition hours—speeches—informal. Secure tickets at registration desk.

Wednesday, January 24

9:30 a. m.—Technical Session—Hotel Statler (Grand Ballroom).
Report of Committee on Research, W. L. Fleisher, Chairman.
The Peripheral Type of Circulatory Failure in Experimental Heat Exhaustion—The Role of Posture, by R. W. Keeton, F. K. Hick, Nathaniel Glickman and M. M. Montgomery.
Advantages of Bactericidal Ultra-Violet Radiation in Air Conditioning Systems, by H. C. Rentschler and Rudolph Nagy.
Seasonal Variation in Reactions to Hot Atmospheres, by F. C. Houghten and A. A. Rosenberg.
10:00 a. m.—Ladies—Open for Shopping.
12:00 noon—Heating and Ventilating Exposition—Lakeside Hall.
2:00 p. m.—Technical Session—Hotel Hollenden (Grand Ballroom)—Joint Meeting with National Warm Air Heating and Air Conditioning Association—Co-chairmen, Pres. J. F. McIntire, ASHVE, and Pres. L. R. Taylor, NWAHACA.
Address by Charles H. Mylander, Columbus, Ohio.
National Warm Air Research, by F. L. Meyer.
ASHVE Research, by W. L. Fleisher.
Performance of a Stoker-Fired Warm-Air Furnace as Affected by Burning Rate and Feed Rate, by A. P. Kratz and S. Konzo.
2:30 p. m.—Ladies Bridge—Halles Tea Room.
4:00 p. m.—Ladies Tea and Fashion Show—Halles Tea Room.
7:00 p. m.—Annual Banquet and Dance — Hotel Statler (Grand Ballroom) — Presentation of Past President's Emblem — Toastmaster — Walter Klie.

Thursday, January 25

10:00 a. m.—Technical Session—Hotel Statler (Euclid Ballroom).
Factors Affecting Duct Friction, by J. B. Schmieler, F. C. Houghten and Harold T. Olson.
The Performance of Stack Heads, by D. W. Nelson.
Installation of Officers.
12:00 noon—Heating and Ventilating Exposition—Lakeside Hall.
12:00 noon—Rotary Club Luncheon (Grand Ballroom Hotel Statler) for Rotarians and Guests—Speaker: Dr. C.-E. A. Winslow. Subject: The Air Cooled Human Body.
1:00 p. m.—Industrial Rayon Corp.—Painesville* (Windowless, completely conditioned plant). Transportation $1.00 per person (round trip).
1:00 p. m.—Inspection Trips.*
1:30 p. m.—Council Meeting—Hotel Statler (Tavern Room).

Friday, January 26

12:00 noon—Heating and Ventilating Exposition — Lakeside Hall.

*For Ladies' Trip Tuesday and Men's Inspection Trips sign up for transportation at the Registration Desk. Limit of 30 persons for the inspection trip to Industrial Rayon due to necessity of guides.

Programs for the Meetings

National Warm Air Heating and Air Conditioning Association—Hollenden Hotel

44th Convention

Tuesday morning, January 23

Chairman, L. R. Taylor.

A Welcome to Cleveland, Hon. Harold L. Burton, Mayor.

President's Message, L. R. Taylor.

Address, Charles M. White.

Don't Overlook the Gravity Furnace, by C. Ackerson.

The Three Bogeymen, by C. T. Burg.

The Publicity Campaign, by Allan P. Ames.

Tuesday afternoon, January 23 (Research Session)

Research Is a Stimulant to Management, Operation and Sales, by C. A. Olsen, Chairman.

Report of Research Advisory Committee, by F. G. Sedgwick, Chairman.

"Winter Air Conditioning-Forced Warm Air Heating," Heat Insulation, by A. P. Kratz.

Resistance of Air Flow to Registers and Grilles, by S. Konzo.

Tuesday evening, January 23

Smoker and Floor Show—Courtesy Northern Ohio manufacturers and jobbers (Grand Ballroom, Hotel Hollenden), Chairman, Jim Wilcox.

Wednesday morning, January 24

Chairman, H. P. Mueller.

Our Installation Codes, by B. F. McLouth, Chairman, Installation Codes Committee.

Sizing Registers for Forced Air and Air Conditioning Installations, by J. H. Van Alsburg.

Advertising and Merchandising Clinic, by F. E. Mehrings, Chairman, Merchandising Committee.

Our Over-All Merchandising Interest, by Jan S. Irvine.

Round Table Discussion.

Ninth Annual Short Course—Year Around Furnace Air Conditioning, by L. G. Miller.

Election of Officers.

Wednesday afternoon, January 24

Joint Meeting with the American Society of Heating and Ventilating Engineers. Chairmen—J. F. McIntire, President, American Society of Heating and Ventilating Engineers, and L. R. Taylor, President, National Warm Air Heating and Air Conditioning Association.

The Research Activity of the American Society of Heating and Ventilating Engineers, by W. L. Fleisher.

The Research Activity of the National Warm Air Heating and Air Conditioning Association, by Frank L. Meyer.

The Bank of the Future, by Charles H. Mylander, Banker and Analyst.

Performance of a Stoker-Fired Warm Air Furnace as Affected by Burning Rate and Feed Rate, by A. P. Kratz and S. Konzo.

Thursday, January 25

Inspection trip to the new strip mill of the Republic Steel Corp. housed in buildings covering 21 acres and located at the mouth of the Cuyahoga River.

THE WEEK AT A GLANCE

EVENTS: Sixth International Heating, Ventilating and Air Conditioning Exposition
46th Annual Meeting, American Society of Heating and Ventilating Engineers
44th Convention, National Warm Air Heating and Air Conditioning Association

PLACE: Cleveland, Ohio
Exposition—Lakeside Hall
ASHVE—Hotel Statler
NWAHACA—Hollenden Hotel

TIME: Exposition—Opens 2:00 p. m., Monday, January 22, and 12 noon other days. Closes 10:30 p. m. each evening. January 22-26
ASHVE—Registration, committee meetings Monday, January 22, 8:30 a. m.
Technical Sessions: Tuesday, Wednesday, Thursday, January 23, 24 and 25. Joint session ASHVE-NWAHACA Wednesday, 2:00 p. m.
NWAHACA—Technical and business sessions Tuesday and Wednesday, January 23 and 24. Joint session with ASHVE Wednesday, 2:00 p. m.

List of Exposition Exhibitors and Their Exhibits

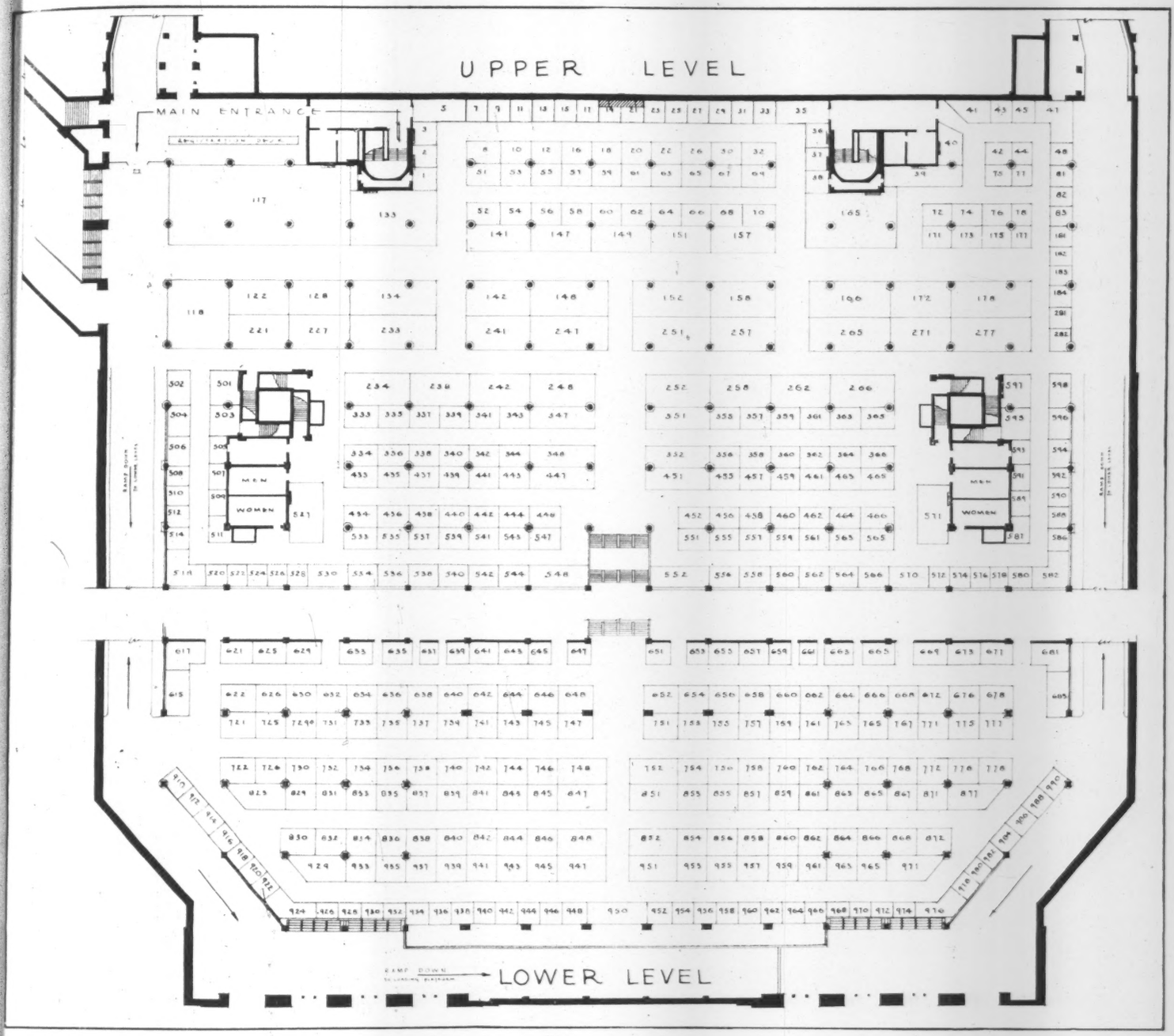
The following pages give you in condensed form the essential information about all exhibitors and exhibits that will appear at the Sixth International Heating and Ventilating Exposition. The listings below include, in alphabetical order, the names of exhibiting manufacturers, their booth numbers, the names of their representatives in attendance, and a brief description of the products they will display. In addition, there is a diagram of the exhibit hall which will enable you to quickly locate the booth of any exhibitor.

HEATING, PIPING AND AIR CONDITIONING's representatives will be at Booth 141 during the exposition, and will be glad to furnish visitors to the show with any additional information they may wish to have.

A busy and profitable week is in store for all who attend the show, according to information already available about the various exhibits. A considerable number of new products will be shown for the first time, and, in addition, a great many exhibits will show equipment in actual operation.

A

NAME OF EXHIBITOR	BOOTH NO.	REPRESENTATIVES IN ATTENDANCE	PRODUCTS ON EXHIBITION
Aerofin Corp., Syracuse, N. Y.	227–233	W. A. Evans, Geo. H. Cummins, M. Noble	Extended surface heating & cooling coils
Air Control Products, Inc., Muskegon, Mich.	598	Robert L. Leigh, H. G. McKee, E. G. Slater	Air conditioning registers and grilles; damper control sets; gravity registers
Air Controls, Inc., Cleveland, Ohio	341–343	B. G. Krause, R. B. Thompson, G. Schwarz, R. B. Dalton, A. Galaba	Filter units; blowers; blower parts; ventilators
Aire-O-Zone Corp., Chicago, Ill.	82		Direct-fired air conditioner
Air-Maze Corp., Cleveland, Ohio	535	F. M. Paul, G. M. Walton, H. H. Schaaf, P. C. Hungerford, C. J. Glanzer, C. Kozell, H. M. Flaherty, R. R. De Vere	Air filter panels for air conditioning and ventilating
Air Conditioning & Oil Heat, New York, N. Y.	548		Publication
Airtemp Div., Chrysler Corp., Dayton, Ohio	41–42–43 44–45–47 48 and 75–77		Compressors; air conditioning units; direct-fired winter conditioners for oil or gas; oil burners
Aldrich Co., Peorin, Ill.	922–924	L. I. Aldrich, N. E. Aldrich, Frank Kupel, John Hassinger, Wm. B. McCarter	Numerous models of domestic oil burners
Allis-Chalmers Mfg. Co., Milwaukee, Wis.	642–644–646		Motors; pumps; V-belt drives
Aluminum Aircell Insulation Co., Detroit, Mich.	742	J. E. Hebberd	Building, duct, and furnace reflective insulation
American Air Filter Co., Inc., Louisville, Ky.	464–466	W. M. Reed, H. C. Murphy, J. R. McConnell, G. W. Sonntag, Jr., A. S. Lewis, Jr., F. K. Minor, A. F. Saunders, E. W. Shaver, Wm. Seelbach, J. D. Reed, I. B. Helburn, J. H. Milliken, O. C. Ross	New automatic self-cleaning electric precipitator; automatic, permanent, and throw-away air filters
American Artisan, Chicago, Ill.	141	See Keeney Publishing Co.	Publication
American Brass Co., Waterbury, Conn.	277		Copper tubes with wrought copper and cast bronze fittings for heating, refrigeration, and air conditioning lines; copper sheet; copper-silicon alloys for ducts and tanks
American Gas Association, New York, N. Y.	165		Exhibiting gas-fired equipment of American Radiator Co., Ira E. Baker Co., Bastian Morley Co., Inc., Bryant Heater Co., Burnham Boiler Co., Cleveland Heater Co., Detroit Lubricator Co., Forest City Foundries Co., Gas Equipment Co., General Controls Co., Hotstream Heater Co., Lennox Furnace Co., L. J. Mueller Furnace Co., Reznor Mfg. Co., Servel, Inc., Surface Combustion Corp., Waterman-Waterbury Co., Westinghouse Elec. & Mfg. Co., White-Rodgers Elec. Co.
American Machine and Metals, Inc., DeBothezat Ventilating Equipment Div., East Moline, Ill.	53		See DeBothezat Ventilating Equip. Div.
American Metal Hose Branch, American Brass Co., Waterbury, Conn.	277		Vibration eliminators of flexible seamless bronze tubing; bronze steam hose; flexible seamless bronze refrigeration charging assemblies
American Radiator & Standard Sanitary Corp., Pittsburgh, Pa.	117	V. L. Francisco, W. L. Tulburt, R. J. Milholland, H. A. Guthman, J. E. Lamping, H. P. Allen, A. L. Vanderhoff & Staff	Boilers; oil burners; radiators; water heaters; copper pipe and fittings; heating accessories; furnaces and air conditioners
American Rolling Mill Co., Middletown, Ohio	271	Tom Byrd, Nick Tiedeman, Ray Sloan, John Anderson	Paintgrip sheets; stainless steel sheets; zincgrip sheets; galvanized sheets
American Society of Heating and Ventilating Engineers, New York, N. Y.	503	Society staff	Society activities
American Steel & Wire Co., Cleveland, Ohio	438–440 and 537–539		See U. S. Steel Corp.
American Stove Co., Lorain Div., Lorain, Ohio	836		
American Viscostat Co., Chicago, Ill.	641	C. B. O'Hare, J. L. Robinson, G. A. Kotas, R. N. Springgate, F. R. O'Hare, W. N. Miller	Fuel oil viscosity control; fuel oil pre-heater
Anchor Post Fence Co., Fluid Heat Div., Baltimore, Md.	929–933		See Fluid Heat Div., Anchor Post Fence Co.



Layout of Lakeside Hall showing the booth locations

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Anderson Products Inc., Cambridge, Mass.	541	Walter G. Ferguson, Warren T. Ferguson, L. L. Lasher, J. Blanchard, I. Upton	Air valves
Anderson Co., V. D., Cleveland, Ohio	56	W. J. Gleason, W. L. Norrington, G. P. Schumacker, W. P. Nevins, George G. Semans, R. C. Chelius	Steam, air, and moisture traps; air valves; strainers
Anemostat Corp. of America, New York, N. Y.	527		High velocity air diffuser; combination diffuser and lighting unit
Armstrong Machine Works, Three Rivers, Mich.	7	O. E. Ulrich, T. H. Rea	Steam traps; steam type humidifier purger for foul gases in refrigeration systems
Atlantic Valve & Pump Co., Chicago, Ill.	17	Edwin B. Tidd, John W. Moore, Forrest A. Johnson	Warm water heating specialties; indirect submerged water heaters electrical controls
Atlas Ball Co., Philadelphia, Pa.	730		
Auer Register Co., Cleveland, Ohio	647	George R. Metzger, George Auer.	Air conditioning and gravity registers and grilles
Auto-Heat Corp., New York, N. Y.	333–335	Otto B. Moody	Oil burners and boiler-burner units
Automatic Burner Corp., Chicago, Ill.	560–562	W. A. Doermann, Stanley Perry	Oil burners; air conditioners; boiler burner units; range burners
Automatic Gas Steam Radiator Co., Pittsburgh, Pa.	514	G. W. Blackmore, W. W. Woodroof, J. B. Selover	Unit heaters; gas steam radiators conversion burners
Automatic Heat & Air Conditioning, Chicago, Ill.	59–61		Publication
Automatic Products Co., Milwaukee, Wis.	437–439	R. W. Johnson, E. A. Vallee, A. A. Anderson, Donald Tmey, M. K. Jasperson, R. D. Marshall, Delmar Moerick	Refrigeration, heating and air conditioning controls
Autovent Fan & Blower Co., Chicago, Ill.	448	Tom Brown, C. E. Wandas, H. W. Kaiser	Propeller fans; volume blowers; unit heaters; V-belt drive unit blowers; kitchen cabinet ventilators; night air cooling fans
B			
Baker Ice Machine Co., Inc., Omaha, Nebr.	74	C. A. Baker, Charles Knox, V. E. Kauffman, August Huenecke, W. L. Ecabert, Roger Sprague, J. C. Vaught, Geo. Sebree, F. T. McDonough	One Freon condensing unit; two Freon compressors
Baldor Electric Co., St. Louis, Mo.	442		Electric motors
Barber-Colman Co., Rockford, Ill.	171–173	R. P. Dewey, C. J. Braatz, E. S. Huffman, V. M. Lathers, T. K. Greenlee, N. E. Smith, L. E. Slawson	Electric temperature controls; grilles and high velocity air diffusers
Barber Gas Burner Co., Cleveland, Ohio	654	H. M. Mansfield, Wm. J. Dueblin, Chas. Stine, E. W. Wolf, F. Brennen, D. Manuel, Chas. Holt.	Gas burners; gas pressure regulators gas valves; automatic control
Barnes & Jones, Inc., Jamaica Plain, Boston, Mass.	334	Walter E. Barnes, William T. Jones	Thermostatic radiator traps; float and thermostatic traps; boiler return traps; modulation radiator valves; packless, quick-opening radiator valves; strainers; orifices; cage type replacements; steam proportionator systems of zone control
Beaver Pipe Tools, Inc., Warren, Ohio	352	E. R. Barkley, J. A. Thornton, Avery Phillis	Portable electric pipe and bolt machines; hand cutters; threaders; reamers; vises; etc.
Beckett Engineering Co., R. W., Elyria, Ohio	725	R. W. Beckett, Stanton Fitzgerald	Oil burner; new boiler unit
Bell & Gossett Co., Chicago, Ill.	64–66		Forced hot water heating systems; indirect water heaters; flow control valves; domestic water temperature controls; booster pumps; compression tanks; relief and reducing valves; electrical controls; fittings
Bethlehem Foundry & Machine Co., Bethlehem, Pa.	951	C. S. Dieter, J. H. Van Sciver, J. B. White, J. Toner	Boiler-burner units and conversion oil burners
Bethlehem Steel Co., Bethlehem, Pa.	434–436	A. A. Warg, F. W. Milburn, C. B. Momberger, J. A. Erze, Beauvis Duffy	Sheets, shapes and pipe
Bishop & Babcock Mfg. Co., Cleveland, Ohio	744	Walter Root, Larry Zarbock, Ray Ramsey, Don Stroud, Joseph Brainard, Melvin Metzger	Ventilating fans; heating specialties; air conditioning blowers
Black & Decker Mfg. Co., Towson, Md.	640	Wm. J. Fenwick, L. B. Fitzgerald, J. F. Apsey, Jr., Wm. G. Williams	Electric tools
Boston Draft Control Co., Boston, Mass.	63–65		See Field Mfg. Co.
Breuer Electric Mfg. Co., Chicago, Ill.	509	R. G. Breuer, R. R. Janke	Portable furnace and boiler vacuum cleaners
Brown Instrument Co., Philadelphia, Pa.	552-556-558		See Minneapolis-Honeywell Regulator Co.
Bryant Heater Co., Cleveland, Ohio	147-149-151	Lyle C. Harvey, Gordon Rieley, W. Randolph Lacey, J. N. Crawford, W. E. Stark, F. R. Higley, E. R. Downe, J. E. Kinner, C. H. Cummings, J. M. Fisher	Gas-fired heating and air conditioning equipment, including boilers, gravity furnaces, forced air furnaces, vertical furnaces, unit heaters, dehumidifiers
Buffalo Forge Co., Buffalo, N. Y.	241	F. W. Swan, C. C. Cheyney, T. A. Weager, R. E. Sherman, C. A. Booth, W. R. Heath, A. A. Criqui, E. F. Wendt, F. B. Stubinger	Ventilating fans; water spray cooling cabinet; new unit heater; suspended evaporative condenser; noise meter
Burdett Mfg. Co., Chicago, Ill.	621	F. W. Grantham, D. A. Jacobson, E. H. Perkins, T. P. Tesmer, J. E. Veihl	Gas burners
Burnham Boiler Corp., Irvington, N. Y.	122		Boilers; radiators; specialties
C			
Canton Stoker Corp., Canton Ohio	630		Stokers
Carbondale Div., Worthington Pump & Machinery Corp., Harrison, N. J.	543–547		See Worthington Pump & Machinery Corp.

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Carey Co., Philip, Lockland, Cincinnati, Ohio	657	H. A. Fox and others	Asbestos prefabricated air duct; pipe covering; rockwool insulation
Carnegie-Illinois Steel Corp., Pittsburgh, Pa.	438–440 and 537–539		See U. S. Steel Corp.
Carrier Corp., Syracuse, N. Y.	227–233	L. G. Powers, Margaret Ingels	Refrigeration compressors; unit air conditioners; unit heaters; outlets; cold diffusers; evaporative condensers
Carter Coal Co., New York, N. Y.	947		
Celotex Corp., Chicago, Ill.	534	I. L. Birner, W. J. McCauley, C. J. O'Grady	Insulation
Central Die Casting & Mfg. Co., Inc., Chicago, Ill.	755	L. J. Sebek, J. A. Franklin	Pulleys; flexible couplings; shaft collars; die castings
Century Electric Co., St. Louis, Mo.	748		Complete line of motors for heating, air conditioning and refrigeration
Century Engineering Corp., Cedar Rapids, Ia.	148	Jos. A. Lattner, M. D. McWilliams, E. E. Scott, George K. Kelley, S. P. Densmore, C. E. McGregor	Conversion oil burners; boiler-burner units; furnace-burner units; domestic water units
Chace Co., W. M., Detroit, Mich.	637	S. R. Hood, C. F. Alban, C. W. Bloch	Thermostatic bimetals
Char-Gale Mfg. Co., Minneapolis, Minn.	738	A. A. Horwitz	Prefabricated air conditioning ducts and fittings; registers; furnace fittings and supplies
Chase Brass & Copper Co., Inc., Waterbury, Conn.	659	W. M. Mulholland, A. F. Sheldon, J. S. Coe, A. E. Dillingham, V. H. Eggert	Spiral-fin tube; copper tube and sweat fittings; headers; screw machine parts; stampings; forgings
Chicago Filter Co., Joliet, Ill.	15	L. D. McGrew, Art Meiche, A. H. DeWees	Air filters for homes, automobiles, railway cars
Chicago Pump Co., Chicago, Ill.	265	M. I. Weil, H. E. Martin, G. L. Thom, A. K. Baker	Return line vacuum heating pumps; condensation pumps; horizontal split-case pumps; close-coupled motorpumps; vertical enclosed-shaft and open-shaft pumps
Chrysler Corp., Airtemp Div., Dayton, Ohio	41–42–43–44–45–47–48 and 75–77		See Airtemp Div., Chrysler Corp.
Cleveland Steel Products Corp., Toridheet Div., Cleveland, Ohio	839–841–843	George Rakovan, D. W. Rouse, L. F. Frett, J. F. Donnelly, J. A. Lappin, R. J. Long, O. C. Parker, J. L. O'Brien, W. J. Smith	Oil burners; boiler-burner units; air conditioning furnaces; gravity furnaces; water heaters
Cole-Sullivan Engrg. Co., Minneapolis, Minn.	281	A. D. Cole, H. J. Sewell, E. W. Laudert, I. E. Loring	Draft governors; draft stabilizers
Columbia Steel Co., San Francisco, Cal.	438–440 and 537–539		See U. S. Steel Corp.
Comfort Products Corp., Harvey, Ill.	83	B. J. Spitzka, J. F. Coyle, T. P. Gloppen	Portable room conditioner; air washing, filtering, circulating, and humidifying equipment; direct-drive variable speed blowers
Commercial Filters Corp., Boston, Mass.	528	E. W. Sherburne	Furnace fuel filters; positive filters for fuel pumps
Commercial Investment Trust, Inc., New York, N. Y.	984–986		
Conco Corp., Mendota, Ill.	938–940	R. W. Conkey, W. G. Van Etten, W. S. Michael, M. J. Murray, H. W. Winningham, L. H. Klinger, H. F. Dean, W. W. Hallinan	Stokers; oil burners; winter conditioners
Cook Electric Co., Chicago, Ill.	939	E. H. Ziebold, K. C. Gillette, A. M. Wilkins	Controls for heating and air conditioning systems; metal bellows
Crane Co., Chicago, Ill.	252–258		Boilers and radiators; oil burning warm air conditioner; oil burner; boiler-burner unit; stoker-boiler unit; winter air conditioning unit; prefabricated duct system
Crowe Name Plate & Mfg. Co., Chicago, Ill.	512		Decorative metal parts; clock & instrument dials; nameplates
Curtis Refrigerating Machine Co., St. Louis, Mo.	747	H. C. Morrison, H. J. Nettler, A. L. Baker, E. Gygax, E. S. Lape, H. J. Campbell	Refrigerating and air conditioning equipment
Cyclone Fence Co., Waukegan, Ill.	438–440 and 537–539		See U. S. Steel Corp.

D

Dayton Rubber Mfg. Co., Dayton, Ohio	564–566	T. C. English, T. C. Davis, J. D. Hershey, Karl H. Glanton, R. L. Wetzel	Cog-belts; V-Belt drives; fractional hp. belts
DeBothezat Ventilating Equip. Div., American Machine & Metals, Inc., East Moline, Ill.	53	C. W. Anderson, A. R. Stephen, A. M. Harp, E. O. Martinson, R. W. Denman	Ventilating sets; bifurcators; fans; agitator; power roof ventilator
Detroit Lubricator Co., Detroit, Mich.	570	P. S. Russel, A. G. Hann, E. J. Doucet, F. D. Cooper, H. L. Walker, J. S. Snyder, F. G. Coggin, W. H. Krack, F. A. Koch, A. A. Putt	Automatic, mechanical, and electrical controls and equipment for heating, cooling, and air conditioning
Dole Valve Co., Chicago, Ill.	633		Air and vacuum valves
Domestic Engine & Pump Co., Shippensburgh, Pa.	635	A. E. H. Berchem, Wm. E. Berrington, Wm. R. Berrington	Vacuum heating pump
Domestic Engineering, Chicago, Ill.	59–61		Publication
Domestic Engineering Catalog & Directory, Chicago, Ill.	59–61		Publication
Dongan Electric Mfg. Co., Detroit, Mich.	837	L. J. Hicks, G. J. Scherling, H. H. Littlebury, C. G. Odell, L. P. Murphy	Ignition transformers
Dowagiac Steel Furnace Co., Dowagiac, Mich.	356–358	R. S. McNaney, Arthur Wick, A. F. Frazee, Graham Woodhouse, John Cunningham, Lou Silverthorn, Laurel Brown, John Walz, Harry Hartung, Carleton Behrmann	Steel furnace; oil-fired and gas-fired winter air conditioners; stoker-fired furnace; blower conditioning unit

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Doyle Vacuum Cleaner Co., Grand Rapids, Mich.	21	Dewey I. Doyle, Geo. D. Crow	Furnace and boiler vacuum cleaner
Dunham Co., C. A., Chicago, Ill.	251		Heating systems
Duo-Therm Div., Motor Wheel Corp., Lansing, Mich.	463–465		Winter air conditioning units; automatic oil furnace
E			
Eagle-Picher Sales Co., Cincinnati, O.	1–2	John Tilden, J. H. Eisaman, Harold Powell, F. J. Bell, N. A. Blair, T. C. Carter, E. L. Gouedy, Douglas Via, J. L. Ash, Glen J. Christner	Insulation
East Ohio Gas Co., Cleveland, Ohio	165		
Electrol, Inc., Clifton, N. J.	944–946–948		Conversion oil burners; boiler-burner units; direct-fired units; split system conditioners; room coolers
Emerson Electric Mfg. Co., St. Louis, Mo.	533	R. E. Otto, O. D. Metz, Wm. Fraser, V. Maurer, R. Dehlendorf, T. Egan, G. Reindel, Jr.	Motors up to 5 hp.; attic, kitchen, and exhaust fans
Evans Products Co., Detroit, Mich.	733–735		Winter air conditioners
Excelsior Steel Furnace Co., Chicago, Ill.	914	C. E. Glessner, F. E. Ford, C. A. Gustavson, W. R. Lawson, R. H. Bristol, J. W. Westwick, John Fehlig, Jr., W. F. Menk	Oil burning air conditioner; forced air ducts and fittings
F			
Fafnir Bearing Co., New Britain, Conn.	753	R. F. Steeneck, S. M. Cooper, A. L. Maltman, F. Leister, T. H. Schebrat, R. W. Powell	Ball bearings
Fairbanks, Morse & Co., Chicago, Ill.	559–561	J. W. Bostwick, W. S. Adams, H. E. Baker, C. H. Turner	Three and five ton self-contained units; remote units; ten ton compressor
Field Mfg. Co., Chicago, Ill.	63–65	Fay L. Kinne, Don Van Etten, Walter Thor	Barometric draft controls; barometric controls with motor attachments
Fitzgibbons Boiler Co., Inc., New York, N. Y.	142	Paul K. Addams, and others	Boiler-burner units; direct-fired conditioners
Fluid Heat Div., Anchor Post Fence Co., Baltimore, Md.	929–933		Oil burners, water heaters; winter conditioning furnaces, boiler-burner units
Forest City Foundries Co., Cleveland, O.	23–25	W. L. Seelbach, I. E. Seith, J. Grouse, A. Bastian, L. Koch, W. Sullivan, W. Kremser, R. Strangward	Coal-fired and gas-fired gravity and air conditioning furnaces
Fowler-Becker Publishing Co., Inc., New York, N. Y.	853–855–857		Publications
Freeman Stoker Div., Ill. Iron & Bolt Co., Chicago, Ill.	10	J. M. McClintock, J. G. Beard, F. W. Cochrane, G. B. Riddle	Stokers
Frick Co., Inc., Waynesboro, Pa.	751	W. H. Aubrey, C. C. Smith, F. R. Zumbro, J. H. Carter, P. H. Buch, W. O. Kline, J. A. Mikesell, P. A. Willis, George B. Bright, Theo. Huetteman, R. C. Doremus, Henry J. Mollenberg, Charles B. Carr, Thos. C. McKee, R. W. Neitzel	Five-ton unit air conditioner; Freon compressors
Friez & Sons, Julien P., Div. of Bendix Aviation Corp., Baltimore, Md.	536–538	Denis McCormack, George F. Knowles, John R. Onderdonk, Elliott Fansler	Instruments and controls for automatic heating, refrigeration and air conditioning
Fulton Sylphon Co., Knoxville, Tenn.	363–365	E. D. Rogers, F. C. Reeder, L. S. Dysart, C. O. Petterson, Chas. A. Wheeler	Temperature controls
Furblo Co., Hermansville, Mich.	638	G. A. Voorhees, L. W. Gillespie, C. H. Lighthart, N. E. Hill, F. G. Herman	Air circulating blowers
G			
General Controls Co., Glendale, Cal.	5	H. G. Wasserlien, E. T. Howard, J. Hammond, A. F. Read, W. G. Griggs, C. C. Tischler	Automatic temperature controls
General Electric Co., Schenectady, N. Y.	157		Motors and controls
General Electric Co., Air Cond. Dept., Bloomfield, N. J.	158 and 257		Air conditioning and heating equipment
General Furnaces Corp., New York, N. Y.	942	Harper Holt, A. P. Saha, William Palm	Oil-fired boiler-burner unit; instantaneous water heater
General Refrigeration Corp., Beloit, Wis.	636		Refrigeration and air conditioning equipment
General Regulator Corp., Chicago, Ill.	27	F. S. Matheny	Domestic, commercial, and industrial ventilating equipment
Gilbert & Barker Mfg. Co., Springfield, Mass.	68–70	H. F. Tapp, C. B. Cooley, W. N. Heseltine, J. A. MacDonell, D. B. Lawrence	Domestic and industrial oil burners; warm air conditioning unit; oil-fired boiler unit; hot water heater
Globe Machine & Stamping Co., Cleveland, Ohio	181	John Remesch, L. H. Seaman, R. T. Williams, A. J. Freiheit, R. E. Wilcox	Grilles; stampings; tumbling barrels; circulating heaters; mouldings
Grinnell Co., Inc., Providence, R. I.	242		Pipe hangers; traps; Pipe fittings; welding fittings; unit heaters; automatic sprinklers
H			
Harris & Co., Arthur, Chicago, Ill.	639	George C. Harris	Floats
Hart & Cooley Mfg. Co., Holland, Mich.	530	R. W. Blanchard, J. H. Van Alsburg, L. E. Heasley, G. Heeringa	Double deflection registers with turning-blade valves; gravity registers
Heating Journals, Inc., New York, N. Y.	548		Publication
Heating, Piping and Air Conditioning, Chicago, Ill.	141	See Keeney Publishing Co.	Publication

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Heating & Ventilating, New York, N. Y.	910–912		Publication
Heat Reclaiming Devices, Inc., Niles Center, Ill.	928		
Heil Co., Milwaukee, Wis.	455–457–459	Joseph F. Heil, C. B. Tamm, George Hochstein, Lee Hanson, Sam Tuttas, H. F. Pugh, Herman Frentzel, C. R. Buller	Oil-fired and gas-fired air conditioning units; boiler burner unit; oil burners
Henry Furnace and Foundry Co., Cleveland, Ohio	656–658	H. F. Curtis, J. L. Rushton, Ross Sharp, E. N. Moncrief	Coal, oil and gas, heating and air conditioning equipment.
Hilo Varnish Corp., Brooklyn, N. Y.	72	K. C. Tucker, C. J. Schumann, G. F. English, A. S. Ledbetter	Industrial finishes
Hoffman Specialty Co., Inc., Waterbury, Conn.	128	A. F. H. Scott, M. C. Gillett, Frank Gaylord, W. A. Russell, J. C. Murphy	Air valves; float and thermostatic traps; hot water controlled heat system; vacuum and condensation pump
Hotstream Heater Co., Cleveland, Ohio	441–443	O. A. Reiter, G. G. Gebhart, L. R. Mendelson	Draft regulators; water heaters; new indirect heater; new combustion test kit

I

Ilg Electric Ventilating Co., Chicago, Ill.	338–340	C. G. McKinley, D. A. Ferguson, C. W. Dexter, J. M. Frank, P. D. Briggs	Fans; blowers; unit heaters; kitchen ventilators; ceiling type cooling and heating unit; dark room ventilator
Illinois Engineering Co., Chicago, Ill.	221	J. L. Ehretsman, R. W. Leutweiler, J. C. Matchett, R. L. Gifford, A. L. Browne, I. H. Geiger, L. B. Pittock, H. W. Conrad, J. D. Shaughnessy	Selective pressure heating control systems, generation and flow types
Illinois Iron & Bolt Co., Freeman Stoker Div., Chicago, Ill.	10		See Freeman Stoker Div., Illinois Iron & Bolt Co.
Illinois Testing Laboratories, Inc., Chicago, Ill.	651	M. D. Pugh, E. F. Burke, J. A. Obermaier	New air velocity meter; resistance thermometers; pyremeters and accessories
Imperial Brass Mfg. Co., Chicago, Ill.	76	A. W. Avery, J. Allman, G. Franck, W. Hartman, W. A. Leonard, F. C. Shafer, C. H. Benson, R. McIntosh, L. C. Coombs	Sump pump; valves; brass tube fittings; tube cutters; flaring tools; tubing benders; dehydrators; strainers; floats.
Independent Pneumatic Tool Co., Chicago, Ill.	838		
Independent Register Co., Cleveland, Ohio	451		Air conditioning registers and grilles
Industrial Press, New York, N. Y.	910–912		Publications
Ingersoll Steel & Disc Div., Borg-Warner Corp., Chicago, Ill.	757		Sheets; solar heat resisting screen.
Insto-Gas Corp., Detroit, Mich.	858		
Iron Fireman Mfg. Co., Cleveland, Ohio	952–954–956–958	C. T. Barg, Dale Wylie W. F. Gleeson, E. C. Webb, K. E. Saboe	Stokers

J

Janette Mfg. Co., Chicago, Ill.	625		Blower wheels; D.C. to A.C. rotary converters; motorized speed reducers
Jefferson Electric Co., Bellwood, Ill.	745	C. T. Harnett, F. H. Pickerill	Oil burner ignition transformers; mercury switches and controls
Jenkins Bros., New York, N. Y.	118	A. J. Yardley, C. C. Chamberlain, J. E. Hodgkins, R. E. MacDowell, V. B. Nickerson	Bronze, iron, and steel valves in various pressures and end styles; mechanical rubber goods; gauge glasses; composition discs
Johns-Manville, New York, N. Y.	342–344		Insulation
Johnson Co., S. T., Oakland, Cal.	950	Robert P. Johnston, M. Ratcliff, Nathan Feldman, J. C. Johnson, H. W. Leeper, Gardner Murray	Oil burners; air conditioning units; indirect split systems; furnaces; water heaters; boiler-burner units
Johnson Service Co., Milwaukee, Wis.	571	P. D. Gayman, J. S. O'Gorman, Jr., T. D. Boyd, M. A. Benson, G. R. Anderson, M. M. Herrick, R. A. Merck	Automatic temperature control for heating, cooling, ventilating, air conditioning, and industrial processes.

K

Kaustine Co., Inc., Perry, N. Y.	12 and 16	J. B. McInnow, L. L. Peeke, W. A. Seitz	Air conditioning furnaces
Keeney Publishing Co., Chicago, Ill.	141	F. P. Keeney, W. J. Osborn, R. P. Wettstein, C. E. Price, R. A. Jack, C. M. Burnam, Jr., J. D. Wilder, J. D. Thomas	Books and publications
Kehm Corp., Chicago, Ill.	721	H. S. Kehm, H. R. Coleman, C. G. Newton, J. W. Manny	Hot water heating specialties
Kent Co., Inc., Rome, N. Y.	9		Furnace vacuum cleaners
Kewanee Boiler Corp., Kewanee, Ill.	117	A. L. Vanderhoof and Cleveland staff	Boilers; heaters; coils; tanks
Kleen-Heet, Inc., Chicago, Ill.	560–562	David Laine, J. W. Hirsch	Oil burners; air conditioners; boiler burner units
Koppers Coal Co., Cleveland, Ohio	960–962	V. L. Ott, J. J. Sidebotham	Processed pocahontas stoker coal

L

Lamneck Products, Inc., Columbus, Ohio	551–553–557	Ralph E. Leffler, Edward H. Paul	Prefabricated duct and fittings for residential air conditioning; furnace pipe and fittings
Lau Blower Co., Dayton, Ohio	847		Blower assemblies, wheels, housings; furnace blower units; night air blowers; pulleys; furnace casing moulding

M

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Macrae, Inc., Brooklyn, N. Y.	643		Oil burners; boiler-burner unit
Magnet Switch Co., Chicago, Ill.	526	T. C. Russell, Tom Russell, Jr.	Room thermostats; draft controls
Maid-O'-Mist, Inc., Chicago, Ill.	524	Wm. J. Woolley, O. V. Woolley.	Humidifiers; water line control valves; boiler water feeder and cut-outs; water softeners; air eliminators
Marsh Corp., Jas P., Chicago, Ill.	69	A. D. Rose, A. C. DuPerow, A. E. Tomlinson, P. B. Howard, Henry T. Kucera	Heating specialties; industrial instruments; gauges; thermometers; temperature regulators
Maurey Mfg. Corp., Chicago, Ill.	572	S. R. Noble, Joseph Maurey, Carl A. Miller, Warren Baldwin, H. N. Davis	Steel and cast iron "V" pulleys; fan
May Oil Burner Corp., Baltimore, Md.	30–32	Edward P. Hayes, Charles R. Collins, J. Geartner, Joseph C. Hauf, Jr., Gene Hauf, J. O. Miller, C. M. Viley	Oil burners and oil burning furnaces and conditioners
McAlear Mfg. Co., Chicago, Ill.	635	Wm. E. Berrington, Wm. R. Berrington, Wm. Ludvik, Steve Pocsik	Steam heating specialties, traps, valves, and controllers
McCord Radiator & Mfg. Co., Detroit, Mich.	739	W. G. Hancock, R. H. McGeorge, F. Longyear, J. R. Hayward, D. J. Mull	Steam, hot water, and gas unit heaters; blast heating and cooling coils
McDonnell & Miller, Chicago, Ill.	182–183	E. N. McDonnell, Bruce P. Adams, Jack McDonnell, Al Porter	Boiler water feeders; low water cut-offs; humidifier water controls
Mercoid Corp., Chicago, Ill.	563–565	Hugh Courteol, I. E. McCabe, J. W. Owens, R. F. Fisher, A. N. Schultz, W. K. Stauffer, W. L. Colterjohn, A. S. Widowfield, W. Ufer, Myron Wimmer, Cliff Grube, John Jex, Jr., Burt Power, B. L. Lerch, W. Lischett	Automatic controls for oil burners, stokers, air conditioning and refrigeration equipment, and various industrial applications
Meriam Co., Cleveland, Ohio	661	J. B. Meriam, A. A. Hejduk, Charles Meriam, H. R. Bowers, J. B. Meriam, Jr.	Manometers; flow meters; pressure gauges; draft gauges
Metal Stamping & Mfg. Co., Cleveland, Ohio	737	Thompson Morrison, Hunter Morrison, Jr.	Blowers
Meyer & Bro. Co., F., Peoria, Ill.	36	Geo. Harms, Ervin Eichenberger, Art Kinsner, R. B. Dickson, J. F. Klein	Furnace pipe and fittings; forced air ducts; registers; fans; blowers
Meyer Furnace Co., Peoria, Ill.	37–38	See F. Meyer & Bro. Co.	Gravity and forced air furnaces
Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.	552–556–558	H. E. Chapler, W. J. Brown, C. C. Cochran, A. C. Grant, C. D. Lyford, L. H. Johnson, E. K. Scoggin, F. E. Walbridge, F. E. Snowberg, C. W. Nessell, J. E. Robb, A. E. Petersen, H. Seelbach, D. J. Peterson, J. C. Dorsey, A. B. Newton, J. E. Haines, R. H. Sweeney, R. A. Wilson, W. L. McGrath, Mel Hamilton, F. Purcell, C. B. Sweatt, W. L. Huff, Tom McDonald, J. W. Pauling, A. H. Lockrae, H. F. Dever, W. J. McGoldrick, A. E. Michelson, Chandler Murphy	Temperature, humidity, and refrigeration controls
Modine Mfg. Co., Racine, Wis.	752	A. G. Dixon, O. E. Desmond, G. A. Rock, A. F. McGovern, M. J. Druse	Unit heaters; copper convectors; cooling coils; blast heaters; air conditioners
Monarch Mfg. Works, Inc., Philadelphia, Pa.	282	J. M. Carroll, E. B. Frame, T. W. Murphy	Oil and water atomizing nozzles; fuel units and pumps; flexible couplings; regulating valves and strainers
Monmouth Products Co., Cleveland, Ohio	3	Mr. Barnes, O. J. Kuenhold, and others	Humidifying equipment
Motor Wheel Corp., Duo-Therm Div., Lansing, Mich.	463–465		See Duo-Therm Div., Motor Wheel Corp.
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.	364–366		See Streamline Pipe & Fittings Div.
Mueller Furnace Co., L. J., Milwaukee, Wis.	134	H. P. Mueller, C. L. Hewitt, Jr., N. M. Blanchard, R. M. Rosebrough, D. E. Cummings, J. G. Werner, M. L. LaVorgna, W. H. McKaig, R. A. Warner, H. B. McKee, E. H. Saunders, K. T. Davis, G. E. McDonough	Coal, oil, and gas-fired winter air conditioning units
Murray Corp. of America, Detroit, Mich.	918–920	H. C. Beresford, W. H. Kuhn, L. E. Walsh	New electric stoker

N

Nash Engineering Co., South Norwalk, Conn.	248 and 347	I. C. Jennings, G. B. Wright, E. A. Mead, J. B. McGregor, C. A. Saints, J. C. Noyes, Jr., J. T. Reader, A. E. Fisher, A. B. Singleton, C. H. Love	Return line heating pumps; condensation pumps; sewage pumps; sump pumps; air compressors; vacuum pumps
National Machine Works, Chicago, Ill.	67	Barney Olson	Power gas conversion burners
National Tube Co., Pittsburgh, Pa.	438–440 and 537–539		See U. S. Steel Corp.
Nesbitt, Inc., John J., Holmesburg, Philadelphia, Pa.	501	A. J. Nesbitt, H. Berkley Hedges, H. C. Porter, John M. McElgin, D. C. Wiley	Heating surface; water cooling coils
Niagara Blower Co., New York, N. Y.	175–177		
Norge Heating & Conditioning Div., Borg-Warner Corp., Detroit, Mich.	433		Air conditioning and automatic heating products

O

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Ohio Foundry & Mfg. Co., Steubenville, Ohio	953	W. L. Sharpe, G. H. McFadden, W. G. Overmyer, C. J. Grayson	Gas room heaters; forced air gas circulators; floor furnaces; bath room wall heaters
Oilheating & Airconditioning Fueloil Journal, New York, N. Y.	853–855		Publication
Olson, Inc., Barney, Chicago, Ill.	67		See National Machine Works
Oster Mfg. Co., Cleveland, Ohio	634		Pipe tools and machinery
Owens-Corning Fiberglas Corp., Toledo, Ohio	846–848	Jan S. Irvine, C. L. Rowley, W. H. Atkinson, J. C. Solon	Air filters; insulation

P

Pacific Gas Radiator Co., Huntington Park, Cal.	758–760		Gas-fired heating and air conditioning equipment
Pacific Lumber Co., Chicago, Ill.	81	John H. Klass, Marvin L. Fergestad, Stanley H. Dickson, Nels P. Waite	Wool insulation
Patterson-Kelley Co., Inc., East Stroudsburg, Pa.	462		"Freon" water cooler
Peerless Electric Co., Warren, Ohio	461	I. F. Delehanty, W. S. Kingsbury, Wm. Moore, R. W. Swift, R. W. Best	Blowers; fans; motors; fan blades; blower wheels; package units; cabinets
Peerless Mfg. Corp., Louisville, Ky.	662		Stokers
Penn Boiler & Burner Mfg. Corp., Lancaster, Pa.	968–970	E. C. Stauffer, J. B. Stauffer, H. C. Altenburg, S. J. Cipoletti	Burner boiler unit; winter air conditioner units; domestic water heater; oil burners
Penn Electric Switch Co., Goshen, Ind.	55–57		Controls for heating, air conditioning, and refrigeration
Perfection Stove Co., Cleveland, Ohio	133	C. H. Foulds, G. B. Ober, W. R. Wright, J. H. Hosier, L. E. Cady, E. B. Goodwin, R. A. Walls, A. J. Horn	Oil-burning and gas-burning air conditioning furnaces
Perfex Corp., Milwaukee, Wis.	52–54	J. K. Luthe, F. D. Hansen, B. L. Boalt, H. E. Lindemann, Shepard Barnes, R. H. Brady, Allen Butler, D. G. Spahr, L. B. Miller, R. H. Pratt, W. R. Miller	Controls for automatic heating and air conditioning
Petroleum Heat & Power Co., Stamford, Conn.	518–520	C. E. Shields, A. E. Hess, G. T. Kaufman, J. F. Corrigan	Domestic and industrial oil burning equipment and accessories
Petrometer Corp., Long Island City, N. Y.	63–65	Dan Bierman	Distant reading tank gauging equipment
Pittsburgh Lectrodryer Corp., Pittsburgh, Pa.	511		Drying equipment
Plumbing & Heating Journal, New York, N. Y.	586		Publication
Plumbing & Heating News, Chicago, Ill.	59–61		Publication
Pocahontas Fuel Co., Inc., Cleveland, Ohio	930–932–934–936	J. Hadley, G. Weigle, J. A. Davidson, W. L. Higgins, F. Snyder, R. Erickson	Automatic bin-feed, ash-removal stoker for bituminous coal; winter air conditioning units
Power Plant Supply Co., Cleveland, Ohio	635	Wm. E. Berrington, Wm. R. Berrington	See Domestic Engine & Pump Co., McAlear Mfg. Co., Wienman Pump Co., Roots-Connersville Blower Corp.
Progressive Co., Chicago, Ill.	982		
Propellair, Inc., Springfield, Ohio	845	J. B. Shaver, V. W. Sharpe	Propeller fans for general ventilation and duct systems
Pyrolite Products Co., Cleveland, Ohio	19	N. B. Radabaugh, H. G. Gaberdiel, C. Schrank	Refractories; furnace cement; heat-resisting paint

Q

Quaker Mfg. Co., Chicago, Ill.	22 and 26	A. T. Atwill, D. J. Howard, H. G. Hays, Sam Johnson, Frank Hohler, W. J. Walkoe	Oil burning furnaces; conversion burners
Quiet-Heet Mfg. Co., Newark, N. J.	935	S. L. La Pidus, R. La Pidus, M. Kish	Oil burners

R

Randall Graphite Products Corp., Chicago, Ill.	447	W. P. Thacher, R. H. Whiteley, M. E. Clark, H. C. Whiteley, G. G. Terris, R. L. Whiteley, C. E. Lowgren, E. A. Lampe	Pillow blocks; graphite bronze bushings; safety collars
Reif-Rexoil, Inc., Buffalo, N. Y.	359–361	Allan F. Reif, Chas. A. Reif, Clarence Beals, Lawrence Knapp	Oil burners; boiler burner units; furnace burner units; winter air conditioners; refractory combustion chambers
Republic Steel Corp., Cleveland, Ohio	166	J. C. Burley, S. D. Yardley, R. W. Baker, F. H. Ramage, R. P. Newall, H. P. Rankin, C. S. French, F. J. Schreiber, A. H. Loranger, R. B. Kelly, M. I. Shea, W. E. Fruhen, R. E. Sonneborn, M. C. Lynch, H. W. Reinker, H. C. Richardson, J. J. Sohm, P. W. Ressler	Galvanized and black sheets; stainless steel; pig iron; pipe; bolts and nuts
Research Laboratory, American Society of Heating & Ventilating Engineers, Pittsburgh, Pa.	506–508		Society research

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Reynolds Mfg. Co., Grand Rapids, Mich.	754		
Richmond Radiator Co., Inc., Uniontown, Pa.	544	C. C. Adams, A. A. Marks, Paul Lawrence, Wm. Paul	Gas fired air conditioner; gas fired boiler; convector radiators; prefabricated air conduit
Ric-wiL Co., Cleveland, Ohio	629	C. Gottwald, M. A. Hanna, F. C. Belser, Val Cotman, Jr., G. P. O'Connor, W. F. Wood, W. L. Bartel	Conduit systems for underground heating plants; water-proof asbestos insulation
Ridge Tool Co., Elyria, Ohio	31–33	C. H. Ingwer, W. L. Parcell, Mitchell Fried, E. C. Bliss	Pipe wrenches; pipe cutters; pipe threaders; pipe vises; extractors; tubing cutters; threading oil
Rome-Turney Radiator Co., Rome, N. Y.	632	W. L. Lynch, J. J. Boylan, E. L. A. Forster, E. J. Parry, W. J. Beasley, J. M. Shannon	Concealed copper radiation; unit heaters; blast air heaters and air cooling coils; refrigeration condensers; helical fin tubing
Roots-Connersville Blower Corp., Connersville, Ind.	635	J. B. Trotman, Wm. E. Berrington, Wm. R. Berrington	All types of turbine pumps
Ruberoid Co., New York, N. Y.	615	J. M. High, P. D. Wersant, Robert J. Baptist, Alfred Gerlach, Thomas Oliver	Pipe covering; insulating jackets for range boilers; insulating blocks for irregular surfaces; insulating cements; asbestos papers and millboard
Russell Co., F. C., Cleveland, Ohio	336		Combination screen and storm window; all metal venetian awning

S

Sarco Co., Inc., New York, N. Y.	238	E. J. Ritchie, and others	Radiator traps; radiator inlet valves; air eliminators; float and thermostatic boiler return traps; bucket drip traps; temperature regulators for hot water heaters and general process work; controls for heating, air conditioning, and refrigeration; pipe line strainers
Schaub Engineering Co., Fred H., Chicago, Ill.	972–974	Fred H. Schaub, Robt. Schaub, Ray C. Moore, R. M. Cherry, M. G. Limbach	Boiler return system; low water cut-off
Scully Steel Products Co., Chicago, Ill.	438–440 and 537–539		See U. S. Steel Corp.
Servel, Inc., Electric Refrigeration & Air Conditioning Div., Evansville, Ind.	622	Harry Newcomb, E. A. Terhune, H. T. Kessler, W. J. Aulsebrook, C. L. Olin, P. B. Reed	Refrigerating machines and compressors for air conditioning
Sheet Metal Worker, New York, N. Y.	502		Publication
S K F Industries, Inc., Philadelphia, Pa.	730	R. H. DeMott, R. C. Byler, F. E. Ericson, R. R. Hirsch, P. R. Payson, C. B. Knowles	Ball and roller bearings and transmission appliances
Skilsaw, Inc., Chicago, Ill.	740	E. W. Ristau, F. M. Goodman, H. H. Thompson	Portable electric saws; drills; grinders; floor and disc sanders
Snips Magazine, Chicago, Ill.	184		Publication
Spang Chalfant, Inc., Pittsburgh, Pa.	756	G. B. Swartz, R. M. Sylvis, C. J. Ramsburg	Pipe
Spence Engineering Co., Inc., Walden, N. Y.	626	Paulsen Spence, N. W. Calvert, Dale L. Prentice, E. J. Richard, C. W. Bell, Jr., Harry Wright, Jr., J. H. Allison, J. H. Menz, Harry A. Neff	Pressure and temperature regulators; governors; desuperheaters
Spencer Thermostat Co., Attleboro, Mass.	435	V. G. Vaughan, R. M. Glidden, N. A. Naylor	Room thermostats; limit controls; fan switches; duct thermostats; stoker timers; gas valves; pilot switches and valves; thermal time delay relays; motor protectors
Standard Lime & Stone Co., Baltimore, Md.	510	John H. Fahy, A. M. Norton, J. M. Daffron, E. E. Kresge	Rock wool home insulation materials
Stanley Electric Tool Co., New Britain, Conn.	677	L. H. Bellows, N. S. Bramer, A. J. Peterson, L. R. Warnock, H. W. Blackman	Motor driven shears; electric drills; electric grinders; diamond wheel dresser
Steel & Tubes Div., Republic Steel Corp., Cleveland, Ohio	337–339	J. F. Keeler, J. N. McGinley	Boiler tubes and heat exchanger tubing
Stoker & Airconditioner Journal, New York, N. Y.	857		Publication
Streamline Pipe and Fittings Div., Mueller Brass Co., Port Huron, Mich.	364–366	C. E. Berry, G. R. Allen, W. A. Blessed, F. L. Riggin, Jr., E. M. Fitzgerald, B. A. Devine, P. H. Berry, H. Scott	Copper pipe; solder type fittings; valves, fittings and accessories for refrigeration
Strong, Carlisle & Hammond Co., Cleveland, Ohio	663	H. Lefoe, N. Smith, R. L. Clark	Steam traps; pressure regulators; separators; strainers; air traps; comb. separator and trap; globe valves; continuous blow-down valves
Sullivan Valve & Engineering Co., Butte, Mont.	504	R. V. Wetzsteon, E. J. Mueller	Room temperature control air valves; positive distributing fittings; draft controls
Sundstrand Machine Tool Co., Rockford, Ill.	645	C. H. Rystrom, B. F. Olson, H. H. Ekstrom, W. A. Kemp	Fuel pumps and fuel units for pressure atomizing oil burners
Surface Combustion Corp., Toledo, Ohio	247	C. B. Phillips, E. A. Weaver, N. B. Buehrer, H. C. Gurney, H. T. Gates, B. Ralph, J. A. Thomas, W. J. Grover, R. L. Towne	Gas-fired winter air conditioners and boilers; conversion burners; unit heaters

T

Taco Heaters, Inc., New York, N. Y.	355–357	E. S. White, R. L. Blanding, J. R. Murphy, J. B. Wallace	Indirect water heaters; circulators and hot water fittings

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Taylor-Winfield Corp., Warren, Ohio	746	John D. Gordon, W. A. Anderson, T. S. Long, E. A. Mallett, F. C. Terry, J. A. Abbott, J. E. Mallett, E. J. Gorde, J. H. Cooper, S. M. Humphrey, H. B. Axtell, E. J. Del Vecchio	Air operated and hydraulic portable welders; stationary spot welders
Tennessee Coal, Iron & Railroad Co., Birmingham, Ala.	438-440 and 537-539		See U. S. Steel Corp.
Thrush & Co., H. A., Peru, Ind.	8	C. L. Sargent, J. J. Munro, H. C. Johnson, R. G. Davis, W. W. Woodroof, Lewis H. Dietz	Circulators; flow control valves; pressure relief valves; pressure reducing valves; heaters; electrical controls
Timken Silent Automatic Div., Timken-Detroit Axle Co., Detroit, Mich.	852-854-856	Willard F. Rockwell, Walter F. Rockwell, T. A. Crawford, M. A. Powers, W. J. Chappell, J. C. Johnson, Ralph Hooke, H. M. Soyster	Oil-fired boiler unit; oil-fired winter air conditioner
Tinnerman Products, Inc., Cleveland, Ohio	734-736	A. H. Tinnerman, G. A. Tinnerman, Wm. M. Buttress, J. M. Stofer, Geo. A. Hansmann, T. O. Dahlstrand	Speed nuts; speed clips
Toledo Pipe Threading Machine Co., Toledo, Ohio	11-13	W. R. Vosper, R. W. Warnke	Power pipe machines; hand-operated pipe tools
Trane Co., La Crosse, Wis.	39-40	R. H. Anderegg, W. Goodman, C. L. Ringquist, E. W. Gray, R. V. Faulks, H. C. Rooks	Convectors; air conditioners; unit heaters; evaporative condensers; compressors; coils; water chiller; heating specialties
Triplex Heating Specialty Co., Inc., Peru, Ind.	522		
Tuthill Pump Co., Chicago, Ill.	648		Pumps for domestic and industrial oil burners
Tuttle & Bailey, Inc., New Britain, Conn	653-655	Stanley Hart, J. H. Smart, T. S. Hart, G. F. Nightingale, F. W. Wills, E. P. Russell, J. W. Maier, F. C. Wetherbee	Grilles; registers; diffusers; air control devices

U

United States Radiator Corp., Detroit, Mich.	234		Boilers; radiators; air conditioning units; heating accessories
United States Register Co., Battle Creek, Mich.	444	Charles J. Pearson, F. C. Bowers, A. A. Stagg, Harry G. Hollman, E. P. Kromdyk	Gravity registers and faces; air conditioning registers, vents and grilles, dampers
United States Steel Corp., Pittsburgh, Pa.	438-440 and 537-539		Galvanized, black iron, copper steel, and stainless steel sheets; tubular products

V

Viking Air Conditioning Corp., Cleveland, Ohio	652	M. I. Levy, A. Bennekamper, W. E. Van Horne, A. W. Lehman, Harry Boling, Frank P. Gibbons	Blower filter units; blower assemblies; blower wheels and housings; bearings; attic fans; humidifiers; water level control valves
Viking Mfg. Corp., Seville, Ohio	834		"Freon" compressors and self-contained units
Vinco Co., Inc.	660		Boiler cleaning and radiator sealing compounds

W

Wagner Electric Corp., St. Louis, Mo.	360-362		Motors for compressors, pumps, water circulators, fans, blowers, unit heaters, stokers; water-cooled motors
Walton Laboratories, Inc., Irvington, N. J.	35	Wm. Feldermann, E. F. Tinnerman, Jr., G. C. Kuffer	Humidifiers
Ward Co., Inc., Edgar T., River Forest, Ill.	617		
Waterloo Register Co., Waterloo, Iowa	505-507	John C. Knox, James F. Northey, Foster H. Benson	Registers; grilles; diffusers; ventilators; dampers
Waterman-Waterbury Co., Minneapolis, Minn.	172	H. G. Cross, A. R. Schwantes, F. G. Sedgwick, Geo. R. Mellema, B. D. Watchler	Furnaces; oil-burning and gas-fired air conditioners; furnace blowers
Watts Regulator Co., Lawrence, Mass.	51	B. E. Horne, Geo. B. Horne, W. M. Dillon, A. J. Harvey, Jr., M. Mercury	Pressure reducing tempering, and relief valves; boiler water feeders; low water cut-offs; circulation controllers
Wayne Oil Burner Corp., Fort Wayne, Ind.	943-945		Oil burners
Weatherhead Co., Cleveland, Ohio	741-743	Norman Paquin, G. R. Whippo, O. C. Wilk	Silica-gel dryer; valves; fittings; receiver tanks
Webster & Co., Warren, Camden, N. J.	152	H. F. Marshall, B. F. Lerch, C. E. Scott, L. H. Plum, C. G. Binder, A. L. Vanderhoof, M. R. Hamlin, F. C. Richardson, Jr., J. A. Hall	Steam heating specialties; lightweight convectors; unit heaters and conditioners
Webster Electric Co., Racine, Wis.	851	E. M. Ford, S. A. Loeb, A. C. Kleckner, P. G. Crewe, H. C. Osborne, V. D. Ott, B. T. Wiechers, D. R. Parker, J. J. Lawler	Fuel units; ignition transformers
Weil-McLain Co., Chicago, Ill.	348	Thos. Regan, Thos. D. Casserly, Don. Kennedy	Boilers and radiators

Name of Exhibitor	Booth No.	Representatives in Attendance	Products on Exhibition
Weinman Pump Mfg. Co., Columbus, Ohio	635	H. W. Vine, Wm. Weinman, Wm. E. Berrington, Wm. R. Berrington	Centrifugal and condensate return pumps
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.	452–456–458–460		Room conditioners; compressors; air conditioning units; gas boilers; oil furnaces; motors; controls; instruments; electric air cleaners; unit heaters; oil burners
White-Rodgers Electric Co., St. Louis, Mo.	540–542	L. F. Blough, Joseph Newman, Jack Searls, J. A. Rodgers, G. R. Gibson, E. E. Harwood, Don Piper, D. O. Eggert, E. E. Stoughton	Limit controls; thermostats; gas valves; stoker controls; damper regulators; fan controls
Whitney Metal Tool Co., Rockford, Ill.	683	Gus Jensen, Herbert Roos	Punches; shears; presses; brakes; angle iron machinery; Pittsburgh lock rolling machine
Whittington Pump & Engineering Co., Indianapolis, Ind.	681		
Will-Burt Co., Orrville, Ohio	978–980	H. E. Wyss, J. R. Luellen, E. G. Baer, R. W. McFadden	Stokers
Williams Oil-O-Matic Heating Corp., Bloomington, Ill.	178		Oil burners; water heaters; air conditioning units
Wilson Co., H. A., Newark, N. J.	937	L. Brock, J. Strong, A. D. Keedwell	Thermostatic bimetals; electrical contacts
Wing Mfg. Co., L. J., New York, N. Y.	78	T. F. Schenke, A. C. Danks	Unit heaters; propeller-fan blowers
Wood Industries, Inc., Gar. Air Conditioning Div., Detroit, Mich.	58–60–62	Frank H. Dewey	Direct-fired air conditioners; boiler-burner units; hot water heaters
Worthington Pump & Machinery Corp., Carbondale Div., Harrison, N. J.	543–547		Central air conditioners; condensing units; compressors; pumps

X

"X" Laboratories, Inc., New York, N. Y.	29	Parke H. Holton	Boiler compounds

Y

York Ice Machinery Corp., York, Pa.	262 and 266	S. E. Lauer, J. R. Hertzler, W. E. Barnum, J. L. Rosenmiller, H. S. Yoder, C. J. Schurman, J. A. Schurman	Sectionalized model of new "Freon-12" compressor; air conditioning units; evaporative condenser; condensing unit; oil and gas fired air conditioning furnaces
York Oil Burner Co., Inc., York, Pa.	840–842–844	A. J. Seiler, E. P. Ryan, G. E. Athana, A. L. Frank, E. I. Kraber, A. Ruff	Conversion burners; boiler units; forced warm air units
Young Radiator Co., Racine, Wis.	351	U. C. Finney, Wm. E. Teklenburg, W. J. Snow, R. D. Ashley, R. A. Mayne, R. H. Biggers, R. C. Coblentz, H. D. McClintock, W. H. Bateman, E. W. Meyer, M. F. May, W. H. Schleck, S. K. Andersen, F. M. Young	Convectors; unit heaters; heating and cooling coils; evaporators; air conditioning equipment
Young Regulator Co., Cleveland, Ohio	926	E. O. Young, Chas. E. Kain, Chas. E. Pidgeon	Damper regulators and dampers
Youngstown Sheet and Tube Co., Youngstown, Ohio	18–20	Walter E. Scott, John M. Tuthill, Geo. V. James, Myron S. Curtis, R. D. McKenzie, C. H. Longfield	Steel sheets

Methods of Establishing *k* Values

How Heat Conductivities Have Been Determined

By Kalman Steiner* and Sydney D. Black†

MODERN handbooks, textbooks, and other sources make technical information easily available to anyone concerned with problems involving heat flow. Few except research workers take the time to investigate the sources of these data, for the engineer is concerned principally with the solution of problems and not with historical anecdotes. There is, however, a fascinating story back of the rather prosaic looking tables of conductivity values that are the tools of the heating, piping or air conditioning engineer. It is a story having its beginning earlier than most of us might at first suspect.

Conductivity values have of course been established for the three states of matter: solid, liquid and gaseous. The actual laboratory experiments were always made with simple geometric forms, for the mathematical derivations of the equations are complex and would lead to insoluble integrations if other shapes of conductors were involved. The use of rods and cylinders was described in the May HPAC; methods utilizing plates, spheres and prisms are discussed here.

Continuous flow methods for determining conductivities for liquids were first employed by Graetz and later by Callendar, who improved on Graetz's method. A continuous stream of liquid whose rate of flow was known was allowed to flow through a long platinum tube heated by an electric current. Knowing the temperatures at the axis and surface of the tube as well as the temperature distribution along the tube, the conductivity of the liquid could be determined.

Plates were possibly first used in the determination of *k*[1] for solids by Lees and later used in an improved method in 1912 by R. Poensgen. Two plates of the same material were placed as shown in Fig. 1 with a separate ring heater to correct for end radiation loss. Temperatures were measured by means of thermocouples. From knowledge of the potential drop across the main heater, the current in the heater, the plate dimensions, the temperature on the two faces of the plate, and the electrical equivalent of heat, the conductivity of the material of the plate can be computed.

Many improvements have been made on Poensgen's method. In 1922 M. Jakob used the apparatus illustrated in Fig. 2 for measuring *k* for liquids and later used similar apparatus in finding *k* for solid plates. In essence, Jakob's apparatus provides for measuring the heat conduction through a plate of liquid 2 mm thick. The copper plates are 4.5 in. in diameter. The distance between plates is maintained by three small glass legs 2 mm high. The liquid was poured in through a hole in the upper copper plate, and was held in place by its own surface tension. Measurements were made on the meniscus before and after the experiment to correct for evaporation losses, as well as for heat transmitted from the meniscus. The experimental data were also corrected for radiation losses. Thermocouples were again employed to measure temperatures.

In other tests on solids the whole apparatus was placed in a Dewar flask. Here one had first to find *k* for the paraffin or oil that was placed between the metal test plate and the copper plates in order that no air gaps should occur. Of course *k* for copper must also be known. This method is adaptable to determining *k* with fair accuracy for solids up to temperatures of 100 C, using a single test plate. At higher temperatures radiation losses become too great. Tests for conductivity of ice plates down to the temperature of liquid hydrogen were made, as well as numerous others.

In order to eliminate radiation losses more effectively, separate heaters were used in another experimental apparatus illustrated in Fig. 3. From a mathematically derived formula involving measurable quantities, *k* could be calculated. Thermocouples embedded at various points in the apparatus permitted of reading the required temperatures.

Poensgen's original two plate method was modified by Honda and Simidu in 1917. Later Konno employed short cylinders of test material in a similar method to that of Poensgen.

Hot Box, Hot Plate, and Nicholls Heat Meter—While the preceding methods on plates are mainly for laboratory work, a number of variations and modifications of them are employed in practical measurements of conductivities in the field. The three principal methods of this nature are the hot box apparatus, the hot plate system, and the Nicholls heat meter. The hot plate system is really Poensgen's method with a guard ring added, and no further discussion will be given here.

The hot box apparatus is a box containing heating elements and fans to gently circulate the heated air. The box is placed against a wall or plate of which the conductivity is to be measured, and is insulated by means of a guard ring and insulating material, from the surrounding room. In this way a known quantity of heat can be sent through the wall, and knowing the drop of temperature through the wall, the conductivity can be determined. This method was first proposed in 1912 by A. H. Barker.

The Nicholls heat meter consists of a cork plate approximately 2 ft square in which are embedded thermocouples by which to measure the difference in temperature of the surfaces of the plate, the entire plate being surrounded by a guard ring. The plate is first calibrated by sending a known quantity of heat through it and noting the temperature difference as read on the thermocouples. By placing the plate on any surface of which conductivity and heat loss are to be determined, and observing the thermocouple readings of temperature difference, the heat transmission and heat transmission

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[1]The coefficient of heat conductivity *k* is expressed in amount of heat transferred per unit time per unit area, and per degree per unit length.

coefficient can be calculated. This method was probably first introduced by K. Hencky in 1919. In 1924 E. Schmidt revised this method in order to measure heat losses and conductivities of pipes. His apparatus consisted of a flexible band of heat resisting material in which were embedded thermocouples in such a manner as to obtain the mean temperature difference between the faces of the band. This band was calibrated in a manner similar to the Nicholls heat meter, and it can be seen that these devices are similar in theory if not in form. In use, the band is wrapped around the pipe and the same procedure followed as in using Nicholl's apparatus.

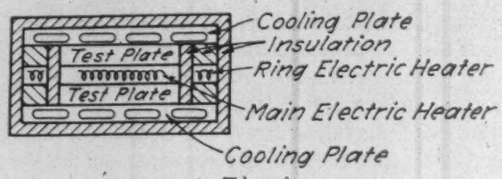

Fig. 1

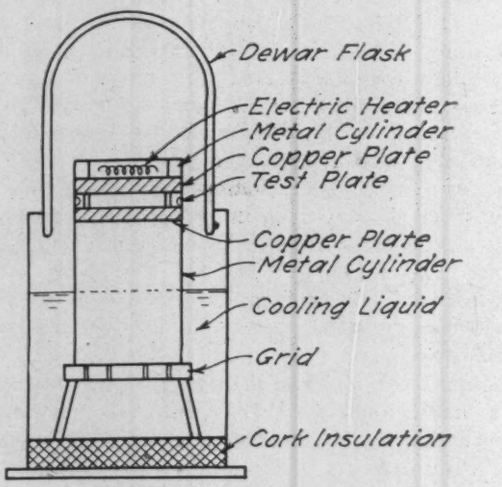

Fig. 2

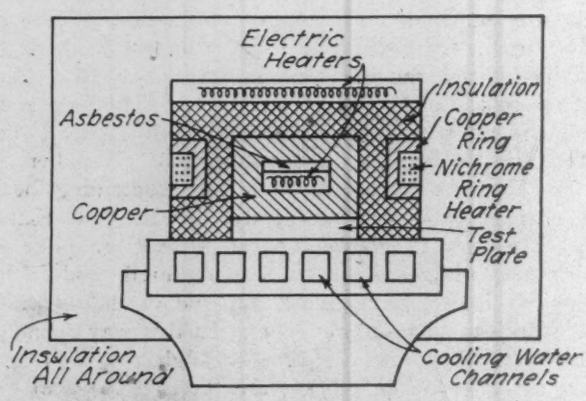

Fig. 3

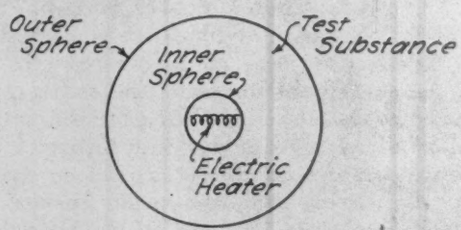

Fig. 4

Spheres—The methods thus far described have utilized rods, hollow cylinders, tubes and plates. Spheres have also been employed for k determinations. C. H. Lees in 1898 measured k of materials by using spheres having electrical heaters at their centers. W. Nusselt used an apparatus as illustrated in Fig. 4 in seeking k values for diatomaceous earth and other materials. In determining k for diatomaceous earth, Nusselt used two concentric spheres. The inner sphere was of thin copper, 1/20 in. thick and 4 in. diameter, and in the center of this inner sphere was supported the electric heating element. Diatomaceous earth surrounded the inner sphere and was in turn encased by an outer zinc sphere that was 1/25 in. thick and 25 in. diameter. Thermocouples were placed in such a way that they conducted away a negligible amount of heat. The entire system was placed in a Dewar flask containing liquid air or other liquid kept at a constant temperature, the zinc sphere being supported only by a stem containing the lead-in wires for the heater and thermocouples. The sphere has been used mostly for finding k values at low temperatures.

Although results have not been good with the sphere method at high temperatures, W. Van Rinsum in 1920 used this method for refractory materials at elevated temperatures. The sphere was divided into eight sectors, a platinum coil being used as the heating element, the whole being heavily heat insulated. The preheating time before a steady state was reached was very long and the experimental difficulties great.

Prisms have also been used for measuring the conductivity of solids, mainly of crystals, wood, bone, and other miscellaneous materials. This method was probably originally devised by H. De Senarmont in 1847. This apparatus, as modified by W. Voigt, was constructed by taking two cubes of different materials, cutting each cube diagonally, and cementing together along the diagonal faces one-half of each cube. A heating element was applied to one of the faces of one of the materials of this composite cube, the latter having first been coated with a wax-like substance having a definite melting point. The substance used for coating was a mixture of elaidin, turpentine and wax, the mixture having a fixed melting point of 44.5 C. As heat is applied to the composite cube, the coating melts, leaving a definite division line between melted and unmelted wax. By noting the angles between the cemented diagonal faces and the line formed by unmelted wax, the ratio of the conductivities of the two solids can be determined. Therefore, if one conductivity is known, the other can be calculated.

The test procedures described in this paper are the principal ones used in laboratory and field work. For a brief summary of the methods for measuring k in practical use the reader is referred to Ezer Griffiths, *Proceedings*, Physical Society, London, 41, 151, 1928. An excellent general text which gives ample treatment to the subject of heat conduction is A Treatise on Heat, by M. N. Saha and B. N. Srivastava. The authors of this article will supply upon request a bibliography of the experiments referred to in the present article.

Heating · Piping and Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

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BULLETIN BOARD

The Northern Ohio Chapter Extends a Hearty Welcome to Cleveland, January 22-26

Method of Choosing Location of, Financing and Conducting Meetings of the Society

Resolved: That inasmuch as the Annual and Semi-Annual Meetings of the Society come under the jurisdiction of the Council, the following rules governing the handling of such meetings be adopted by the Council and published in the JOURNAL of the Society at least twice during every year, preferably just prior to each meeting:

1—The Council will select the city in which the Annual or Semi-Annual Meeting is to be held, giving due consideration to the invitations received from Chapters or members as well as to the advisability of so distributing those meetings as to make them of the greatest advantage to the general membership, and to reduce as far as possible the expense of members attending.

2—That an appropriation be made to cover the entertainment or local expenses, incurred in connection with the meeting not exceeding $500.00, the regular meeting expense to be taken care of by the General Fund of the Society in the regular way.

3—That no registration fee or compulsory obligations of any nature be imposed on members or guests.

4—That the purchase of tickets for banquets or for any other form of entertainment that may be provided be entirely voluntary.

5—That the grouping of features and the sale of tickets for group features be discouraged.

6—That the raising of funds from manufacturers of heating apparatus be discouraged.

7—That the display of samples, or of literature advertising the product of any manufacturer in any way, shape or form, be not permitted at the booths, registration desk, or in or about the meetings.

8—That the distribution of trade papers be entirely at the discretion of the committee in charge.

9—That the local Chapter or local members, be empowered to form a General Committee with such sub-committees as may be required to handle the details of transportation, hotel accommodations, entertainment, finance, etc., and that this General Committee be requested to confer frequently with the Council, through the Secretary of the Society, and to make frequent reports on progress in connection with the various matters being handled by them.

10—That the arrangements of elaborate and costly entertainment features be discouraged.

Adopted at Council Meeting, January 29, 1926.

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Performance of a Stoker-Fired Warm-Air Furnace as Affected by Burning Rate and Feed Rate

By A. P. Kratz* and S. Konzo**, (*MEMBERS*), Urbana, Ill.

Introduction

THE investigations in forced-air heating in the Research Residence at the University of Illinois during the heating season of 1937-1938 were confined to studies[1] of the performance of a warm-air furnace, fired both by hand and by means of an underfeed stoker.

These tests were made with a high volatile bituminous coal obtained from Saline County (5th vein), Illinois. In the stoker-fired plant, shown in Fig. 1, the initial tests were made with the coal feed rate maintained at 48.6 lb per hour and with the quantity of air for combustion adjusted to maintain a burning rate of approximately 18 lb per hour during the *on-periods* of the stoker. For the heating season of 1938 - 1939, these investigations were extended to include the performance with the feed rate reduced from 48.6 lb per hour to 27 lb per hour and the burning rate maintained at 18 lb per hour; and with the feed rate maintained at 27 lb per hour and the burning rate reduced from 18 lb per hour to 13 lb per hour. In order to obtain comparable data at all burning rates and feed rates no changes were made in the furnace, in the plant, in the volume of air circulated, nor in the settings of the thermostats. Furthermore, in all of the tests made with the stoker, 1 in. x 10 mesh stoker coal, washed and oil treated, was used.

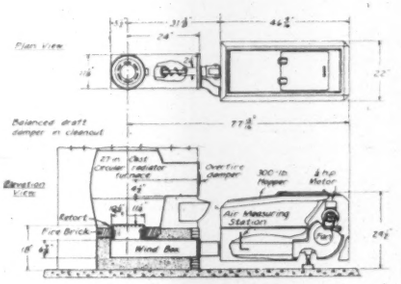

Fig. 1—Diagram of conversion stoker installation in furnace. Research Residence, season 1937-1938, Series 3-37 and 4-37

Description of the Research Residence and Heating Equipment

The Research Residence in Urbana, Illinois, and the forced-air heating plant have been completely described in a previous publication.[2] The residence is a three story structure of standard frame construction. At the time that these tests were made the walls were not insulated. The double-hung windows were not equipped with weather strips, and during the tests they remained tightly locked.

The heating plant consisted of a cast-iron, circular-radiator warm-air furnace used in connection with a forced-air heating system. The principal dimensions are shown in Table 1. A centrifugal fan delivered 1675 cu ft of air per minute through a duct system consisting of two main warm air trunks and three cold air returns.

As shown in Fig. 1, the stoker was of the underfeed type and was inserted through the ash pit door of the furnace. A balanced check damper was installed in the clean out of the chimney. The hopper had a capacity of 300 lb, and coal was delivered to the retort by means of a rotating screw. Both the rate of fuel input and the rate of air supplied to the tuyeres could be independently adjusted. A Pitot-tube, shown at the measuring station in Fig. 1, was used to compute the quantity of air from observations of the velocity at different points in the cross-section of the air tube, and a Wahlen gage was used to measure the velocity pressures.

The heating plant was controlled by a room thermostat operating to start and stop the stoker motor, and to start and stop the circulating fan. The room thermostat was of the heat-anticipating type, and was used in conjunction with two bonnet thermostats[3] which served as high and low limit controls for the temperature of the air in the furnace bonnet.

Table 1—Dimensions and Areas of Furnace Used

Grate diameter	23 in.
Grate area	2.88 sq ft
Firepot diameter	27 in.
Heating surface	
ash-pit	1.36 sq ft
fire pot	8.10 sq ft
dome	18.87 sq ft
radiator	31.93 sq ft
Total	60.26 sq ft
Ratio of heating surface to grate area	20.9
Casing diameter	50 in.
Free area through casing	4.97 sq ft
Combustion space[a]	8.8 cu ft
Free area through over-fire damper	4.9 sq in.

[a]Combustion space is defined in this case as the space above the hearth level, including the dome, but not the feed neck.

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[1]Performance of Stoker-Fired and Hand-Fired Warm-Air Furnaces in the Research Residence, by A. P. Kratz, S. Konzo, and R. B. Engdahl. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, November, 1938, p. 732).

[2]University of Illinois, *Engineering Experiment Station Bulletin No. 266*, by A. P. Kratz and S. Konzo, 1934.

For presentation at the 46th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Cleveland, Ohio, January, 1940.

[3]A complete wiring diagram of the control system is given in the previous paper. Loc. Cit. Note 1.

Method of Conducting Tests

The average of the air temperatures in all of the rooms of the house was maintained at 72 F both day and night. Observations of weather, indoor room air temperatures, room relative humidities, and other incidental data were made daily at 7:00 a.m., 11:00 a.m., 4:00 p.m., and 10:00 p.m. Complete data were obtained for each 24-hour test period on the fuel consumption, weight of ash and clinkers removed, the total integrated time of operation of the fan and of the stoker, the total electrical input of the fan and of the burner motors, and the total number of the *on-periods* of both the circulating fan and stoker. Daily observations were made of the volume of air circulated, and the filters were cleaned with sufficient frequency to maintain the air volume constant. In addition, continuous records of temperatures, CO_2, and the index of smoke density were obtained for each 24-hour period. For each series of tests, data were obtained over a wide range of outdoor weather conditions. For all of the tests made during the two heating seasons with the mechanical stoker, each day at 11 a.m., the clinkers were removed, the fuel bed was levelled, and the hopper was filled with coal. During extremely mild weather no attention was given the fuel bed or hopper, except as required every two or three days. By means of the balanced check damper the draft in the smoke pipe was maintained at approximately 0.05 in. of water.

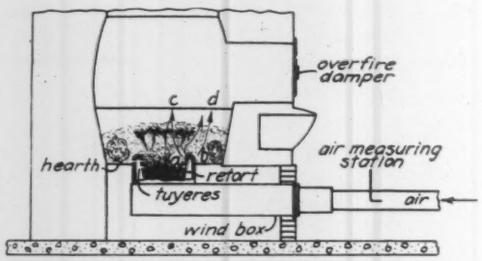

Fig. 2—Flow of air through stoker fuel bed

The following is a description of the different test series, and in every case both the feed rate and the burning rate refer to the rates existing during the *on periods* of the stoker:

Feed Rate 48.6 lb per hour, Burning Rate 18 lb per hour. Overfire Damper Open (Series 3-37): In this series of tests, which was discussed in the previous paper,[4] a high feed rate was used in conjunction with a low burning rate, and the overfire damper in the firing door was open at all times. During the *on-periods* of the stoker the CO_2 content of the flue gas was maintained at approximately 10 to 11 per cent, and a slightly hazy atmosphere over the fuel bed was obtained.

Feed Rate 48.6 lb per hour, Burning Rate 18 lb per hour. Overfire Damper Closed (Series 4-37): In the first series of tests, *Series 3-37*, considerable burning, accompanied by low CO_2 content of the flue gas occurred during the *off-periods* of the stoker. Hence a parallel series of tests, designated as *Series 4-37* and discussed in the previous paper, was conducted with the overfire damper closed.

Feed Rate 27.0 lb per hour, Burning Rate 18 lb per hour. Overfire Damper Closed (Series 1-38, 2-38, 3-38): For the tests conducted during part of the heating season of 1938-1939, the feed rate was adjusted to 27.0 lb per hour and the burning rate was maintained at 18 lb per hour. Thus the feed rate was lower than the corresponding rate maintained in the tests conducted during the heating season of 1937-1938, while the burning rate was the same.

[4]Loc. Cit. Note 1.

Feed Rate 25.8 lb per hour, Burning Rate 13 lb per hour. Overfire Damper Closed (Series 4-38): A series of tests was conducted during the heating season of 1938-1939 with the feed rate maintained about the same as that used in the preceding series, but with the air input to the stoker reduced to maintain a burning rate of approximately 13 lb per hour.

Results of Tests

Determination of Burning Rate

In the case of uniform fuel bed such as that obtained in a hand-fired furnace, the burning, or combustion rate is dependent only on the quantity of air passing through the fuel bed. Kreisinger[5] has indicated that for uniform fuel beds of this nature approximately one half of the air required for complete combustion must be supplied over the fire. Hence, if at any given time the weight of air supplied to the grates and the amount of overfire air are known, an observation of the CO_2 content of the flue gas used in connection with the analysis of the fuel affords a means of calculating the instantaneous rate of burning of any specific fuel. If this rate remains fairly constant, a few observations of the CO_2 will be sufficient to determine a representative mean rate of burning.

The burning rate in the case of a stoker-fired furnace is not necessarily determined by the rate of coal being fed to the furnace. On the contrary, as indicated in the previous paper,[6] good results were obtained with an intermittently fired, warm-air furnace utilizing a high volatile Illinois coal at an intermittent feed rate of 48.6 lb per hour accompanied by an average burning rate of about 18 lb per hour. The burning rate always refers only to the *on-periods* of the stoker, since no accurate determinations of air weights or burning rates could be made during the retarded combustion accompanying the *off-periods* of the stoker.

As shown in Fig. 2, in a non-uniform fuel bed, such as that obtained in a furnace fired by means of an underfeed stoker, the air supplied through the tuyeres is utilized for both *primary* and *secondary* combustion. That is, practically all of the air supplied through the inner tuyeres, *a*, passes through a fuel bed composed of unburned coal and incandescent coke; whereas practically all of the air supplied through the outer tuyeres, *b*, and part of the air supplied through the inner tuyeres, *a*, passes through a porous fuel bed consisting of incandescent coke, clinkers, and loose ash. It follows that the combustion rate is determined by the amount of air that comes into contact with the incandescent coke, all the rest acting as secondary air.

The diagrams in Fig. 3 showing the distribution of CO_2, O_2, and CO over the fuel bed were obtained by traversing the combustion space over the fuel bed with a portable sampling tube made of fused silica and by analyzing the gases in the orsat gas analyzer. These diagrams indicate that the flue gases in that portion of the fuel bed directly above the retort contain appreciable percentages of CO, as a result of the primary combustion that occurs as the air passes through the relatively dense layer of incandescent coal and coke predominant in the middle of the fuel bed. Part of the air which passes through the outer tuyeres and enters the loosely packed

[5]Low Rate Combustion in Fuel Beds of Hand Fired Furnaces, by Henry Kreisinger, C. E. Augustine, and S. H. Katz. (*U. S. Bureau of Mines Technical Paper* No. 139, p. 7).
[6]Loc. Cit. Note 1.

layer of incandescent coke, clinkers, and ash surrounding the middle of the fuel bed, escapes to the surface without coming into contact with the incandescent fuel, as indicated in Fig. 3 by the high concentration of O_2 and the low concentrations of CO and CO_2 in that region. The combustion over the fuel bed is completed when the *secondary* air passing through the outer zone of the fuel bed comes into contact with the unburned gases passing through the center zone of the fuel bed. Hence, in a furnace fired by means of an underfeed stoker, both the *primary* air and *secondary* air enter the fuel bed through the tuyeres in the firepot. In most installations, therefore, it may be expected that the admission of additional *secondary* air through the firing door is not necessary for combustion during the *on-periods*, and results only in a dilution of the flue gases.

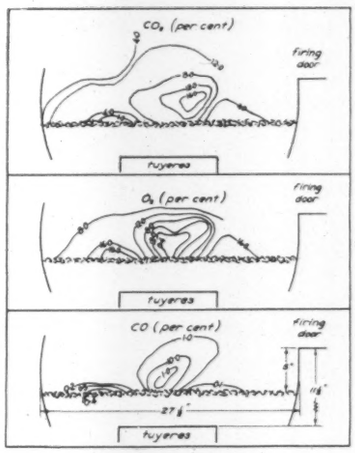

Fig. 3—Distribution of CO_2, O_2, and CO

As with the uniform fuel bed in a hand-fired plant, the burning rate in a stoker-fired fuel bed can be obtained for any specific coal by determining the total quantity of air supplied to the fuel bed and the CO_2 content in the flue gas. If no additional air is admitted through the firing door, the total air supplied to the fuel bed can be determined by measurements made in the air tube leading to the wind box of the stoker. For the test made in the Research Residence plant the burning rate was obtained by using these measurements in conjunction with the CO_2 in the flue gas. For the purpose of measuring the quantity of air, the overfire damper and all joints in the wind box and the firing door, were sealed so that all of the air required for combustion was supplied through the wind box.

Fig. 4 is a chart showing the relations between burning rate, air supply, and CO_2 content for the coal used in these tests. Similar charts can be derived for any other fuel.

Burning Rate and Thickness of Fuel Bed

To a certain extent the frequency and duration of *on-periods* of the stoker depend on the type of heating system in which the stoker is used. In boiler practice the stoker is usually operated infrequently and the *on-periods* are relatively long, whereas in warm-air furnace installations the converse is true. This fundamental difference in the frequency of *on-period* operation for boilers and for furnaces should be appreciated in order to obtain a clearer understanding of the relations that exist between the burning rate, the feed rate, and the thickness of the fuel bed.

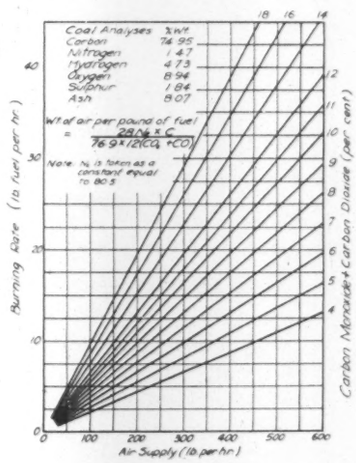
Coal Analyses % Wt
Carbon 74.95
Nitrogen 1.47
Hydrogen 4.73
Oxygen 8.94
Sulphur 1.84
Ash 8.07
Wt of air per pound of fuel = 28.96 x C / 76.9 x (12CO₂ + CO)
Note: N₂ is taken as a constant equal to 80.5
Burning Rate (lb fuel per hr)
Carbon Monoxide + Carbon Dioxide (per cent)
Air Supply (lb per hr)

Fig. 4—Relation between burning rate, $CO_2 + CO$, and air supply

During relatively long *off-periods* of the stoker, the combustion that occurs throughout the period reduces the amount of combustible in the fuel bed, with the result that both the percentage of combustible matter and the thickness of the fuel bed are decreased. Hence, at the beginning of a stoker operation, following a long *off-period*, the flue gas temperature, the CO_2 content in the flue gas and the burning rate are all at minimum value. After the stoker has been operating for a long period of time, the percentage of combustible in the fuel bed and the thickness of the fuel bed both increase. The result is that the air passes through a thicker layer of incandescent coke, and the CO_2 content of the flue gas is increased.

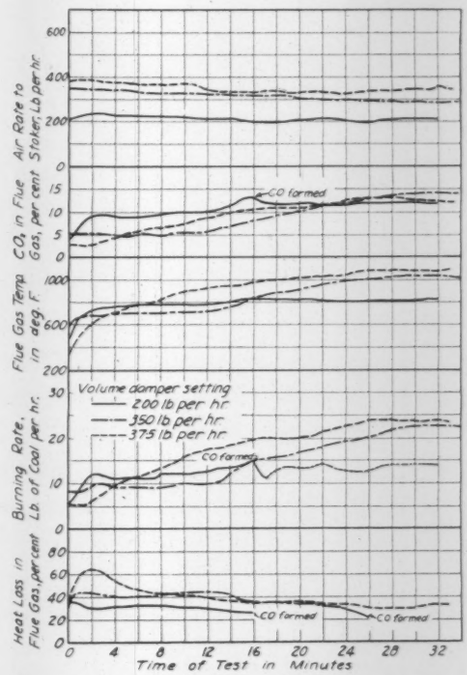
Air Rate to Stoker, Lb per hr
CO₂ in Flue Gas, per cent
CO formed
Flue Gas Temp in deg F
Volume damper setting
200 lb per hr
350 lb per hr
375 lb per hr
Burning Rate, Lb of Coal per hr.
Heat Loss in Flue Gas, per cent
Time of Test in Minutes

Fig. 5—Combustion characteristics for continuous stoker operation (tests preceded by long *off-period*)

The graphical log in Fig. 5 shows the results obtained in the Research Residence plant when the stoker was manually operated so that a long *off-period* was succeeded by a long *on-period*. This condition occurs in the operation of a warm air furnace plant during the morning pick-up following the operation with a reduced thermostat setting at night. With a uniform fuel bed and a constant amount of air supplied to the grates, the combustion rate remains constant, and a few observations of the CO_2 will be sufficient to determine the average combustion rate. In a stoker-fired plant in which the feed rate is greater than the combustion rate, during long *on-periods* a progressive change occurs in the amount of incandescent fuel with which air comes into contact, resulting in a progressive change in the combustion rate, and a large number of CO_2 observations are necessary to determine the progress of the combustion rate.

Because in these tests the air rate was maintained constant by means of the constant volume damper in the stoker air tube, the increase in the CO_2 content, as shown in Fig. 4, was reflected in an increase in the burning rate. For extremely long periods of stoker operation the increases in CO_2, flue gas temperature, and burning rate continued until the burning rate finally approximated the feed rate. Because the coal was being burned as fast as it was fed to the furnace, the thickness of the

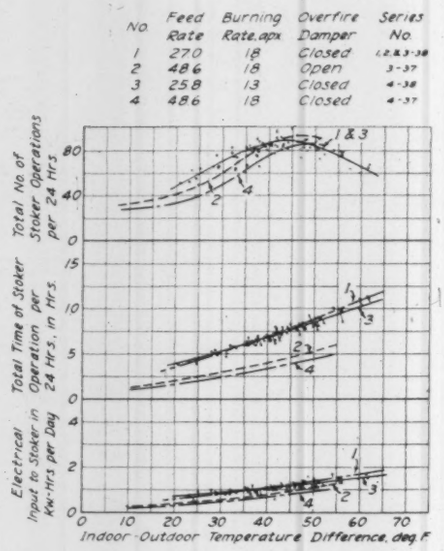
No. Feed Rate Burning Rate, apx. Overfire Damper Series No.
1 270 18 Closed
2 486 18 Open 3-37
3 258 13 Closed 4-38
4 486 18 Closed 4-37
Total No. of Stoker Operations per 24 Hrs.
Total Time of Stoker Operation per 24 Hrs. in Hrs.
Electrical Input to Stoker in Kw-Hrs per Day
Indoor-Outdoor Temperature Difference, deg. F

Fig. 6—Operating characteristics of stoker

fuel bed tended to remain constant, and the combustion may be considered as having attained uniformity with respect to time. Under some conditions with prolonged *on-period* operation, and with low rates of air input the thickness of the fuel bed built up to such an extent that smoky combustion, accompanied by measurable amounts of CO, was obtained. This unfavorable combustion was aggravated when the resistance of the fuel bed surrounding the firepot was excessively large, such as that which occurred when large dense clinkers were formed.

From the standpoint of ideal thermostatic control it is desirable to provide continuous combustion just sufficient at all times to offset the heat losses from the house at all outdoor temperatures. Continuous and modulated combustion is usually not obtained in an intermittently fired heating plant, because the burning rate is adjusted to a maximum value sufficient to heat the house under extreme weather conditions, and the regulation of the combustion rate to satisfy milder heating demands is obtained by intermittent operation of the burner. In the case of a forced air furnace plant, owing to its flexibility and lack of heat storage capacity, long and infrequent operations of the stoker are not conducive to the maintenance of uniform bonnet air temperatures. For this reason the *on-periods* of the stoker should be frequent and of short duration, and active combustion occurring during the *off-periods* serves a useful purpose by tending to minimize the differences between the average rate of combustion and the rates taking place during the *on-periods* and the *off-periods*.

From tests made in the Research Residence it was observed that under normal conditions when the stoker was operated frequently and for short periods, the variations in the flue gas temperatures, in the CO_2 content, and in the burning rate, between the maximum occurring during the *on-periods* and the minimum occurring during the *off-periods*, were not as large as those indicated in Fig. 5, which were characteristic of excessively long *on-periods*. Within one or two minutes after the stoker started, the burning rate attained a value which remained constant until the room temperature rose to normal and the stoker was stopped. This burning rate was less than the feed rate, and in the tests reported in the previous paper,[7] the combustion occurring in the *off-periods* reduced the surplus coal fired into the fuel bed, with the result that the thickness of the fuel bed remained constant during the entire 24-hour test period, even though the feed rate and the burning rate differed considerably. Obviously wide discrepancies between feed rate and burning rate are practical only when the coal can burn freely during the *off-periods* of stoker operation. This would not be true for a stoker having an automatic cut-off in the air tube or when using a strongly coking coal. For a coal which tends to form coke trees, it is probable that the air input should be adjusted so that the burning rate is approximately equal to the feed rate.

Variations in Feed Rate and Burning Rate

The results obtained from the tests made to determine the effect of varying the feed rate and burning rate in an intermittently operated furnace plant are shown in Figs.

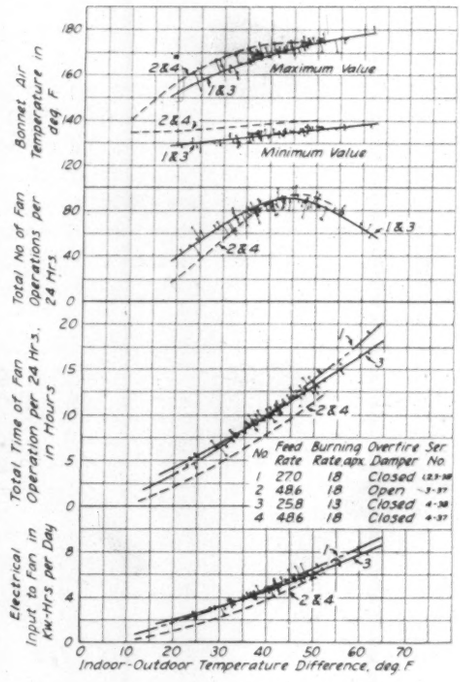
Bonnet Air Temperature in deg. F
Maximum Value
Minimum Value
Total No of Fan Operations per 24 Hrs.
Total Time of Fan Operation per 24 Hrs. in Hours
No Feed Rate Burning Rate, apx. Overfire Damper Ser No.
1 270 18 Closed
2 486 18 Open 3-37
3 258 13 Closed 4-38
4 486 18 Closed 4-37
Electrical Input to Fan in Kw-Hrs per Day
Indoor-Outdoor Temperature Difference, deg. F

Fig. 7—Operating characteristics of fan

6 to 9. Significant values for each 24-hour period were plotted against the difference in temperature existing between the indoors and outdoors for the same period. The plotted points deviate to some extent from the curves representing the average of the observed data, and these deviations can be partly attributed to the wind and sun

[7] Loc. Cit. Note 1.

effects which cannot be represented on curves based on temperature difference alone. For purposes of comparison the curves representing the data obtained during the season of 1937-1938 have been transferred to Figs. 6 to 9, and are designated as curve numbers 2 and 4.

As shown in Fig. 6 the total time of stoker operation per day, and the electrical input to the stoker motor per day, were less for high feed rates than for low feed rates. The unit electrical inputs were approximately 7.8 and 12.9 kwhr per ton for feed rates of 48.6 lb per hour and 26 lb per hour respectively.

The total time of operation of the circulating fan in the forced air system, and the electrical input to the fan motor, as shown in Fig. 7, were also less for high feed rates than for low feed rates. With the higher feed rates, due to a large amount of *off-period* burning, higher average bonnet air temperatures were maintained, as shown in the top part of Fig. 7. As a result of the higher register air temperatures accompanying the higher bonnet air temperatures, shorter periods of fan operation were required in order to cause the room temperature to rise a sufficient amount for the room thermostat to stop the fan and stoker.

The curves in Fig. 8 indicate that minimum average flue gas temperatures and minimum fuel consumption were obtained with a 48.6 lb per hour feed rate, and 18 lb per hour burning rate, and with the overfire damper closed (Curve No. 4). This arrangement was not entirely satisfactory since a smoky flame was obtained during the *off-periods*, thus indicating that with a thick fuel bed, sufficient secondary air was not being admitted through the outside tuyeres, and that it was necessary to augment the *secondary* air by opening the overfire

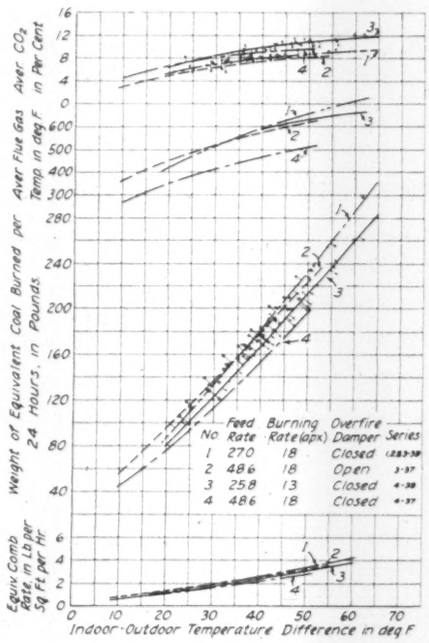
Aver. CO_2 in Per Cent
Aver Flue Gas Temp. in deg F
Weight of Equivalent Coal Burned per 24 Hours, in Pounds
Equiv Comb. Rate in Lb per Sq Ft per Hr
No Feed Rate Burning Rate(apx) Overfire Damper Series
1 270 18 Closed 1,2,3-38
2 486 18 Open 3-37
3 258 13 Closed 4-38
4 486 18 Closed 4-37
Indoor-Outdoor Temperature Difference in deg F

Fig. 8—Performance curves for stoker-fired furnaces

damper. When the overfire damper was open, the smokiness during the *off-periods* was eliminated but the flue gas losses during the *off-period* were larger, resulting in increased fuel consumption, as shown by Curve No. 2. When the same burning rate of 18 lb per hour was maintained and the feed rate was reduced to 27 lb per hour, (Curve No. 1) a thinner fuel bed was obtained. Owing to the evolution of less volatile gases during the *off-period*, the *secondary* air admitted to the fuel bed through

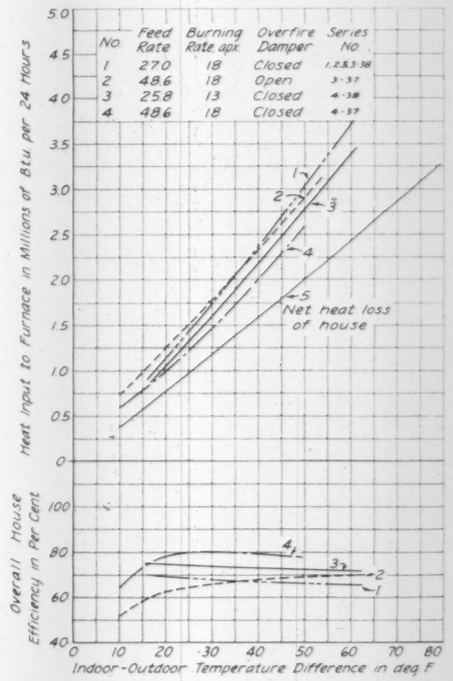
Heat Input to Furnace in Millions of Btu per 24 Hours
Overall House Efficiency in Per Cent
No Feed Rate Burning Rate apx Overfire Damper Series No
1 270 18 Closed 1,2,3-38
2 486 18 Open 3-37
3 258 13 Closed 4-38
4 486 18 Closed 4-37
5 Net heat loss of house
Indoor-Outdoor Temperature Difference in deg F

Fig. 9—Heat inputs to Research Residence

the outside tuyeres was sufficient to eliminate smoke without the admission of air through the overfire damper. The thinner fuel bed was also accompanied by less *off-period* burning and more intense combustion over a smaller area during the *on-period*, thus resulting in higher flue gas temperatures which were reflected in greater fuel consumption than that obtained with the thicker fuel bed under comparable conditions, as shown by Curves Nos. 1 and 4 respectively. There was a greater tendency for the formation of holes in the fuel bed and a greater amount of fly ash was obtained. Therefore, taking all things into consideration, the use of the smaller feed rate cannot be regarded as advantageous for the coal used.

When the burning rate was reduced to 13 lb per hour, which was about enough to take care of the maximum heating demands of the house, and the feed rate was maintained at about 26 lb per hour, (Curve No. 3) the resulting fuel consumption was less than that obtained with an 18 lb burning rate (Curve No. 1). These results confirm the conclusion that minimum fuel consumption was obtained when the maximum combustion rate most nearly conformed to the maximum heating demands of the house, which was drawn in connection with the studies of oil burning[8] in the Research Residence. In the case of the tests represented by Curve No. 3, the *on-period* burning rate was maintained at a low value and, as far as conditions would permit in this type of plant, the operation of the stoker was nearly continuous. On the other hand, for the tests represented by Curve No. 4, in which considerable burning occurred during

[8]Performance of Oil-Fired, Warm-Air Furnaces in the Research Residence, by A. P. Kratz and S. Konzo. (TRANSACTIONS ASHVE, 1937, Vol. 43, p. 215).

the *off-periods,* the average of the combustion rates during the *on-periods* and the *off-periods* was maintained at a minimum value and the *on-periods* were comparatively short.

The fuel quantities shown in Fig. 8 were reduced to terms of heat input to the furnace, in millions of Btu per 24 hours and were plotted as shown in Fig. 9. As explained in the previous paper,[9] the net heat loss from the house (Curve No. 5) was derived from experimental results for heat input obtained with anthracite as a fuel. By using these derived values of the net heat loss from the house in connection with the fuel consumption curves for the stoker-fired plant, the over-all house efficiency, or the ratio of the heat loss from the house to the heat input to the furnace, could be calculated and is shown in the lower part of Fig. 9. For an indoor-outdoor temperature difference of 34 F the over-all house efficiencies ranged from 67 to 80 per cent, with an average of about 70 per cent. This range in efficiencies was reasonably small considering the very large differences in the burning rates and feed rates that were used in these tests. It is apparent that an intermittently operated stoker in a forced-air heating plant is extremely flexible, and that a wide range of adjustments in the air rate and feed rate will give acceptable combustion conditions.

Conclusions

The following conclusions may be considered as applying to the Research Residence and the conditions under which the tests were conducted.

1. The burning rate in the case of a stoker-fired furnace is not necessarily determined by the rate of coal being fed to the furnace, but rather by the rate at which the air is supplied to the fuel bed.

2. In the case of a domestic underfeed stoker, the air supplied to the fuel bed through the tuyeres is utilized for both primary and secondary combustion.

3. With a constant air supply to the fuel bed, the burning rate increases progressively during long *on-periods* of the stoker. During short *on-periods* the burning rate remains comparatively constant.

4. Any combustion occurring in the *off-periods* reduces the surplus coal fired into the fuel bed, with the result that the thickness of the fuel bed tends to remain constant, even though the feed rate is considerably in excess of the burning rate.

5. With a freely burning coal that does not coke strongly, a feed rate only slightly in excess of the burning rate results in a thinner fuel bed and a greater fuel consumption than those obtained with a feed rate considerably in excess of the burning rate.

6. The amount of smoke obtained during the *off-periods* may limit the amount that the feed rate can be in excess of the burning rate.

7. An intermittently operated stoker in a forced-air heating plant is extremely flexible, and a wide range of adjustments in the air rate and feed rate will give acceptable combustion conditions.

Acknowledgments

The results presented in this paper were obtained in connection with the investigation of warm-air furnaces and heating systems in the Research Residence,[10] at the University of Illinois, conducted by the Engineering Experiment Station of which M. L. Enger, Dean of the College of Engineering, is the director, and in the Department of Mechanical Engineering of which O. A. Leutwiler, Professor of Mechanical Engineering Design, is the head. This investigation is a cooperative project sponsored jointly by the *National Warm Air Heating and Air Conditioning Association* and the Engineering Experiment Station. These results will ultimately comprise part of a bulletin of the Engineering Experiment Station. Acknowledgment is made to R. B. Engdahl, Research Assistant, and to D. W. Thomson, Research Graduate Assistant, for their services in conducting the tests and in the reduction of the test data. The assistance of the various manufacturers who cooperated by furnishing instruments and equipment is gratefully acknowledged.

[9] Loc. Cit. Note 1.

[10] The Research Residence in Urbana, Illinois was built, furnished, and completely equipped specifically for research work in warm-air heating by the *National Warm-Air Heating and Air Conditioning Association* in December, 1924.

Air Conditioning Study Course

A course in air conditioning, offering a study of the fundamental principles and of their practical application, has been announced by the Extension Division of the University of Wisconsin, Madison, Wis., as an addition to its service of instruction by correspondence.

The course is designed for men actively engaged in the industry and for others desiring the essential technical information. A good knowledge of arithmetic and the ability to use simple formulas are necessary. Since heating, ventilating, and refrigeration are involved in air conditioning, the fundamentals of these subjects are dealt with.

Among the topics treated are air conditioning standards, humidity and the use of the psychrometric chart, humidifying and dehumidifying, use of tables, heat losses, heat gains, the warm air heating system, combined heating and ventilation and warm air heating, refrigeration principles, air distribution and design of air ducts, radiation for fan systems, calculation of the cooling load for residences, restaurants, etc., by the temperature and solar methods.

J. F. G. Miller Dies

John F. G. Miller, vice-president, B. F. Sturtevant Co., Hyde Park, Boston, Mass., died suddenly at his home in Brookline, Mass., on December 9, at the age of 62. Mr. Miller, a native of Indiana, was born March 23, 1877, and was graduated from Purdue University, class of 1903 with a degree of B.S. While at College he was a four-letter athlete and captained the football, track and basketball teams.

He was a member of the board of advisors of the Purdue Research Foundation, and belonged to the Detroit Chapter, Tau Beta Pi and Phi Delta Theta fraternities.

After serving an apprenticeship with the C. & E. I. R. R., Danville, Ill., as machinist, and upon graduation from Purdue, he entered the employ of American Blower Corp., Detroit, and served as sales engineer, branch manager, vice-president and general manager from 1906 to 1933. He had a wide acquaintance in the ventilating and air conditioning field, and at the time of his death was president of the *Air Conditioning Manufacturers' Association* and director of the *National Association of Fan Manufacturers,* a member of the *ASME* and since 1916 a member of the ASHVE. He was also a member of the Sons of the American Revolution and the Lotos Club of New York.

Surviving are his widow, Mrs. Mary Miller, and two brothers, Hugh T. H. Miller, Columbus, Ind., and S. V. B. Miller, Seattle, Wash., to whom the Officers and Council extend their sincerest sympathy.

The Effect of Lint on Air Filter Performance

By Frank B. Rowley* and Richard C. Jordan** (*MEMBERS*), Minneapolis, Minn.

This paper is the result of research sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in cooperation with the Engineering Experiment Station, University of Minnesota.

IN making laboratory tests on air filters it has been the common practice to use a dust mixture which has been made up from several distinct types of dusts. The elements have usually included some type of carbon black or lampblack in combination with the ash from a specified coal. Other elements such as volcanic ash, pulverized clay, and Fuller's earth have also been used in the dust mixture, and in many cases a single element such as coal ash or some other dust has been used individually. The properties of these materials which affect the performance of an air filter vary through wide ranges, and many laboratory tests have shown that not only are the performance characteristics of a given filter affected by the type of dust used, but that the relative values of two different filters may even be reversed when tested by the same laboratory apparatus and test procedures but with different dust mixtures. The variables due to the different types of dust have been investigated and the results reported in three previous papers.[1, 2, 3]

In practically all previous investigations the dust mixture has contained no lint or fibrous matter, whereas in practice nearly all air to be filtered contains some form of fibrous material, commonly called lint. Fibrous materials will often have a greater effect on the performance characteristics of a filter than will the straight dust mixtures commonly used. An examination of the used filters from many installations will show a mat of lint at the entrance of the filter with very little dust distribution through the filter.

There are many variables in the lint problem such as type of lint, length and diameter of fibers, density, percentage of lint by weight in the total dust in the air, etc. It is, therefore, not possible to get a positive answer which can be applied to all installations, but lint is, nevertheless, a vital factor in the performance characteristics of filters in many practical installations and should be taken into consideration in rating them.

In this investigation there were three distinct problems to consider: *first*, to determine the character of the lint which must be taken out of the air by the average filter installation; *second*, to produce a lint which will simulate as nearly as possible that found in the air and which can be reproduced with reasonable certainty without undue expense; *third*, to study the effect of the lint produced on the performance characteristics of different types of filters.

Type of Lint in Air

An inspection of certain types of filters which have been subjected to air containing lint will show a heavy mat of lint on the entering face of the filter with very little penetration to the interior parts of the filter. It is evident that the lint in this mat, particularly that which is collected on the entering surface near the end of the life of the filter, is representative of that found in the air. Use was made of this principle in selecting samples of atmospheric lint for examination. Four filters, each of which had been in use for a sufficient length of time to be covered on the entering surface with a heavy mat of lint, were selected. Lint samples were taken from them as follows:

A—Lint taken from filter in downtown office building.
B—Same as *A* but taken from different air conditioning system located on different floor of same building.
C—Lint taken from residential filter, suburban district.
D—Lint taken from Pullman car filter.

In each case the sample was removed from the entering surface of the mat, and the mat was of sufficient thickness to insure that no lint could penetrate the filter to any appreciable depth.

In preparing a sample for analysis a small portion of the lint was held over a glass slide and pulled apart to separate completely all fibers. A cover glass was then placed over the fibers, and the analysis was made with a microscope of 100 diameters magnification and a ruled ocular in the eyepiece. The diameters and lengths of from 200 to 400 fibers of each type of lint were measured as closely as possible by the ruled ocular and recorded. These data were then grouped into length intervals of 50 μ (microns) and diameter intervals of 5 μ, and the frequencies with which the fibers occurred in each interval calculated. Naturally, there was some dust in the lint samples, but it was comparatively easy to distinguish between the dust particles and the fibers.

The results of the microscopic analysis of the fibers taken from the various filters are shown in the curves of Figs. 1 and 2 and in Table 1. Frequency plotted against length in microns is shown in the curves of Fig. 1. Due to the facts that the scale for length in microns was extended and that the greater frequencies were in the low range, the length in microns was plotted to a logarithmic scale. It will be noted from these curves that fibers from

*Director, Engineering Experiment Station, University of Minnesota.
**Instructor, Engineering Experiment Station, University of Minnesota.

[1] Air Filter Performance as Affected by Kind of Dust, Rate of Dust Feed and Air Velocity Through Filter, by Frank B. Rowley and Richard C. Jordan. (ASHVE TRANSACTIONS, Vol. 44, 1938, p. 415.)

[2] Air Filter Performance as Affected by Low Rate of Dust Feed, Various Types of Carbon, and Dust Particle Size and Density, by Frank B. Rowley and Richard C. Jordan. (ASHVE JOURNAL SECTION, *Heating, Piping, and Air Conditioning*, June, 1939.)

[3] A Standard Air Filter Test Dust, by Frank B. Rowley and Richard C. Jordan. (ASHVE JOURNAL SECTION, *Heating, Piping, and Air Conditioning*, October, 1939.)

For presentation at the 46th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Cleveland, Ohio, January, 1940.

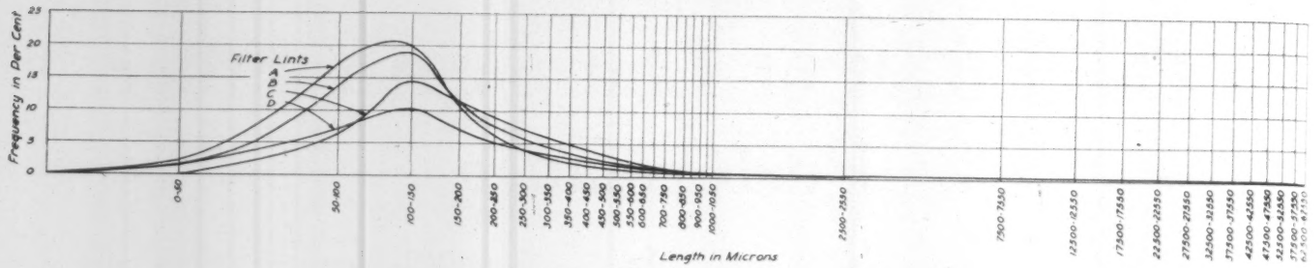

Fig. 1—Length distribution curves for lint fibers removed from filters

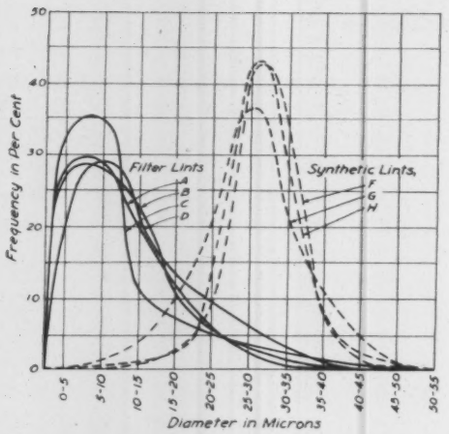

Fig. 2—Diameter distribution curves for filter lint fibers and synthetic lint fibers

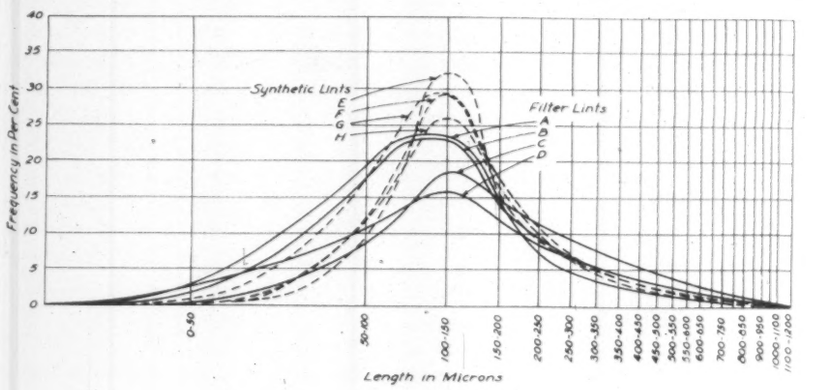

Fig. 3—Length distribution comparison for synthetic lint fibers and filter lint fibers shorter than 1200 microns

100 to 150 μ in length occur in the greatest frequency for all samples. Above 1200 μ there is substantially a linear distribution. The curves of Fig. 1 do not indicate the maximum fiber length for each sample examined since the curves practically join above 1200 μ in length. The longest fibers recorded were 24,317, 29,713, 57,036, and 51,030 μ for samples *A*, *B*, *C*, and *D*, respectively.

The frequency in per cent plotted against diameter in microns for the four samples is shown in the curves of Fig. 2. These curves show that for all samples the maximum diameter frequency is from 5 to 10 μ. Table 1 gives the source and the analysis of the four lint samples. From the curves and the table the following observations can be made: *First*, for all samples the greatest percentage of fibers by length was less than 1200 μ, but the greatest percentage of weight for the entire sample was due to fibers of more than 1200 μ in length. The average measurements for all samples showed that 23 per cent of all fibers was more than 1200 μ in length and that these fibers constituted 86 per cent of the entire weight of the samples. *Second*, the variation in average lint diameter for the four samples was from 10.8 to 13.2 μ. *Third*, the percentage of fibers of greater length than 1200 μ was lowest for the office building, next for the residence, and highest for the Pullman car. The average diameter of fibers for the Pullman was likewise the highest, but the other three were substantially the same. The average length in microns for all fibers was lowest for the office buildings, next for the residence, and highest for the Pullman. However, there was very little difference between the lint samples from the residence filter and those from the Pullman filter. These differences in size between the fibers found in filters for the three different types of installations may be due partly to the average distances between the source of lint and the filters, but are probably largely due to the type of lint generated in the three different installations. There is, however, not a great difference considering the widely

Table 1—Distribution of Fiber Size of Lints Removed from Filters in Actual Use

Sample	Source of Lint	Per Cent of Fibers Greater than 1200 μ Length	Per Cent of Weight Due to Fibers Greater Than 1200 μ Length	Average Diameter in Microns	Average Length in Microns	Average Length in Microns of All Fibers Shorter Than 1200 μ	Average Length in Microns of All Fibers Longer Than 1200 μ
A	Office Bldg. Filter	17.0	77.0	10.8	996	271	4.420
B	Office Bldg. Filter	18.4	86.0	10.5	1415	251	6.500
C	Suburban Residential Filter	22.4	90.0	10.7	2702	378	10.920
D	Pullman Car Filter	35.0	92.0	13.2	2923	364	7.560

different character of the installations. *Fourth,* from the curves it will be noted that there is a much wider spread in fiber length than in fiber diameter for all samples. It should be noted that from 200 to 400 fibers do not give a sufficient sampling to obtain statistically accurate distribution curves and averages. However, the results are sufficiently accurate for purposes of comparison between actual lint found in the air and the artificial lint to be built up for test purposes.

Artificial Lint

In producing an artificial lint to simulate that found in the atmosphere it was necessary to consider both length and diameter of lint fibers. Several different types of materials were considered, including wool, cotton, silk, rayon, and kapok. In general the fibers of these materials were too long and of too large a diameter when compared with those taken from filters. After a considerable amount of experimental work it was found practical to duplicate approximately the long fibers, that is those over 1200 μ in length, by combing out a mat of the fibers and cutting it into $\frac{3}{16}$-in. lengths with a paper cutter. For the short fibers it was found that kapok, when ground in a ball mill for an experimentally determined period of time, broke up into lengths which conformed very closely in frequency distribution of length with the short fibers taken from filter installations. The technique consisted of grinding the fibers for a period of 20 minutes in a ball mill rotating at 60 rpm. The barrel of the mill was 8¼ in. in diameter, and 8¾ in. in length, and contained 150 flint stones of 1-in. average diameter. Four grams of Java kapok were ground and then screened through a 30-mesh screen to remove the coarse, unbroken fibers.

Four samples of Java kapok, designated as *E, F, G,* and *H,* were obtained from different sources and all treated in the manner as previously outlined. After treatment these samples were examined microscopically for diameter and length distribution. The lengths were found to be all under 1200 μ and the greatest percentage of fibers was from 100 to 150 μ in length. The length frequency distribution curves for the kapok fibers and for the filter lint fibers below 1200 μ are shown in Fig. 3. From these curves it will be noted that there is a reasonably close agreement in length frequency distribution between the artificially prepared kapok fibers and the filter fibers below 1200 μ in length. The diameter distribution of the prepared kapok fibers is shown in Fig. 2 in conjunction with the diameter distribution for those fibers taken from filters. It will be noted that the average diameter of kapok fibers is considerably larger than that found in the lint from the filters. There is, however, a very close agreement in the diameter distribution for the fibers from the different samples of kapok lint prepared.

In the ball mill the kapok fibers were broken into shorter lengths, but the diameters were not materially changed. The diameter distribution for the short kapok fibers as shown in Fig. 2 may, therefore, be used as the diameter distribution for the long kapok fibers which were prepared by cutting pads of the kapok as previously described. It was found impractical to prepare any of the other types of lint in the ball mill due to the fact that they were not broken up by the grinding process to an extent equal to that for the kapok fibers. The kapok fibers were found to be rather brittle and easily broken. A criticism of the prepared kapok lint as a test fiber is in the fact that it is of greater diameter than that found in the average filter. The effect of lint on the filter, however, appears to be more a question of fiber length than of fiber diameter, providing the fiber is of a size and density which will float in the air, and will be distributed evenly over the face of the filter. For this reason it seems practical to use the prepared kapok fibers in determining the relative performance of filters with and without lint in the air.

Filter Test Data

As in the previous program, four filters typical of those used in practice were used throughout all of the tests. These filters have been designated by the letters *A-1, B-3, C* and *D,* and their construction was described in detail in a previous paper.[4] A numeral following the designating letter indicates that slight changes had been made by the manufacturers in the filter since it was originally selected. Briefly, the filters may be described as follows:

A-1—A cleanable type oiled filter, 2 in. thick. The filter media was made up of layers of expanded metal and wire screen graded from coarse mesh at the entrance to fine mesh at the leaving side. The filter is 2 in. in thickness, whereas the former filters of this type used in the previous test program were 4 in. in thickness.

B-3—A viscous throw-away type of filter, 2 in. thick. The fibrous media were graded in fiber size, density, and oiling from the entering to the leaving side. Slight changes were made by the manufacturer in this filter since the original selection was made.

C—A cellular type of filter, 2 in. in thickness. The filter was built of two sections, each with honeycomb type of cells set at 45 deg to the center line of the duct, and at 90 deg to each other. The cells in the section on the entering side were of larger dimension than those in the section on the leaving side of the filter.

D—A filter of cotton media consisting of coarse material on the entering side and glazed on the leaving side. The filter media was accordion plaited in the frame to give an area of approximately 12 times the cross-sectional area of the air stream.

In testing these filters both long and short fiber lints were used, and these were mixed with various proportions of dust as indicated in the test results.

In all cases the dust mixture consisted of 80 per cent by weight of Pocahontas ash screened through a 200-mesh screen, and 20 per cent by weight of Double Bolted Carbon Dust screened through 100 mesh. The Pocahontas ash was obtained by burning Pocahontas coal at a rate which was sufficiently low to prevent clinkering of the ash, and the Double Bolted Carbon Dust was obtained from Binney and Smith Co., New York City. When the short fiber lint was used it was mixed with the test dust and fed to the filter by the standard dust feeding apparatus. When the long fiber lint was used, it was necessary to feed it into the air stream separately from the dust. This was accomplished by placing the lint in a copper mesh cylindrical shell closed at both ends and rotated in the inlet air stream leading to the filter. As the cylinder containing the lint was rotated, a jet of

[4] Loc. Cit. Note 1.

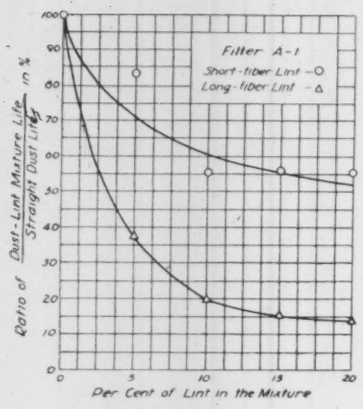
Filter A-1
Short-fiber Lint —O
Long-fiber Lint —Δ
Ratio of Dust-Lint Mixture Life / Straight Dust Life in %
Per Cent of Lint in the Mixture

Fig. 4—Effect of dust-lint ratio on life of Filter *A-1*

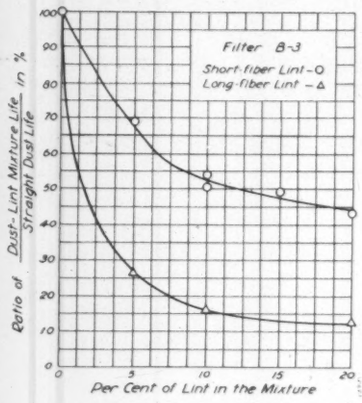
Filter B-3
Short-fiber Lint—O
Long-fiber Lint —Δ
Ratio of Dust-Lint Mixture Life / Straight Dust Life in %
Per Cent of Lint in the Mixture

Fig. 5—Effect of dust-lint ratio on life of Filter *B-3*

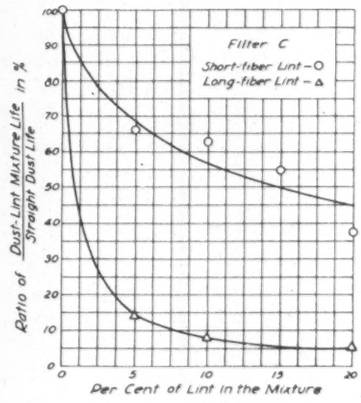
Filter C
Short-fiber Lint—O
Long-fiber Lint —Δ
Ratio of Dust-Lint Mixture Life / Straight Dust Life in %
Per Cent of Lint in the Mixture

Fig. 6—Effect of dust-lint ratio on life of Filter *C*

compressed air was directed tangentially against the cylindrical copper mesh shell, thus forcing the fibers through the mesh of the screen. The amount of lint for a 1-hour test was divided into two parts, ½ being fed into the air stream at the end of the first 15 min of the test, and the second half at the end of the first 45 min of test. Approximately 2 or 3 min were required to feed the lint at each interval. In each test the face air velocity through the filter was maintained at 300 fpm, and the total combined weight of the dust and lint fed was 40 g (grams) per hour. In all cases the length of the test was governed by the time required for the filter resistance to rise 0.25 in. of water. Preliminary tests were made using Java kapok obtained from three different sources in order to determine the uniformity of this material as a test lint. The variations in test results were not appreciably greater than those for a series of tests run on kapok obtained from a single source and tested on the same make of filter.

Tests were run on all four types of filters, using both short fiber and long fiber kapok at percentages of lint ranging from 0 to 20 per cent of the combined weight of lint and dust. Filters *A-1* and *B-3* were also tested on a mixture of lint consisting of 14 per cent by weight of the short lint and 86 per cent by weight of the long lint. This mixture approximated the weight ratio of the two lengths as found in actual installations, and given in Table 1.

The results of the tests are shown in Table 2, and graphically in Figs. 4, 5, 6 and 7 for Filters *A-1*, *B-3*, *C*, and *D*, respectively. The curves show that, with the exception of Filter *D*, there is a rapid drop in life for small percentages of lint mixed with the dust. In each case the long fiber lint affects the life to a much greater extent than the short fiber lint for the same percentage mixture. For Filter *D* the effect of lint on filter life was very much less pronounced than for the other filters. With this filter the actual surface area for catching lint was about 12 times as great as that for the other filters, and since the deposit of lint was mainly on the surface of the filter the results are logical. Furthermore, the lint was of the same general type of material as the filtering media, and lint deposits on the face, therefore, merely had the effect of increasing the thickness of the media. The reason that the short fibers do not affect the life of the Filters *A*, *B*, and *C* to the same extent as the long fibers is that there is better distribution of the short fibers in the interior of the filters, whereas the long fibers tend to mat at a particular section of the media and cause abnormally high pressure drops across such sections.

From Table 2 it will be noted that there is a tendency for an increased arrestance with increasing percentages of lint in the dust mixture. This tendency is somewhat greater for Filters *A-1* and *C* than for Filters *B-3* and *D*. A part of this increased arrestance is probably due to the increase in dust eliminating efficiency of the media when containing lint, and a part to the fact that most filters are practically 100 per cent efficient in the elimination of lint. All arrestances shown are based upon the total weight of dust and lint fed. The arrestance values are substantially the same when using the short fiber lint as when using the long fiber lint for a particular filter.

When 14 per cent of short fibers was mixed with 86 per cent of long fibers, and 10 per cent by weight of this fiber mixture combined with 90 per cent by weight of the dust mixture, the performance characteristics of Filters *A-1* and *B-3* as shown in Table 2 were substantially the same as those for the same filters when using a mixture consisting of 10 per cent of long fibers and 90 per cent of dust. These results are logical since there is about six times as much long fiber by weight as short fiber in the mixture. The probable effect of this preponderance of long fibers is that a part of the short fibers are caught on the surface of the filter by the long fibers and are thus prevented from penetrating to the depth to which they might go if short fibers only were used in the mixture. These tests indicate, therefore, that a relatively long fiber lint might be used satisfactorily for the rating of air filters.

Figs. 8, 9, 10, and 11 show comparisons of the four filters before and after tests with long fiber lint-dust mixture. Table 3 gives a comparison of the distribution of lint in the four filters as determined by examination after the tests. An examination of the filters showed a reasonably even distribution of lint over the face of the 2-in. filters for both the short and long fibers, indicating good distribution of the lint in the test air. In all cases the deposits adjacent to the retaining frames were

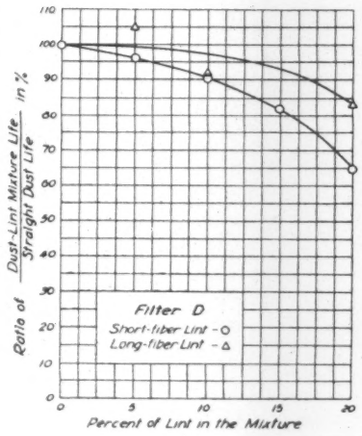
Ratio of Dust-Lint Mixture Life / Straight Dust Life in %
Filter D
Short-fiber Lint - O
Long-fiber Lint - Δ
Percent of Lint in the Mixture

Fig. 7—Effect of dust-lint ratio on life of Filter *D*

slightly greater due to the area restrictions at these points. With the exception of Filter *C*, all lint appeared to be retained in the filter. For Filter *C* a slight trace of very short fiber lint was found in the crucible on the down stream side of the filter.

Conclusions

The conclusions which may be drawn from this investigation are as follows:

1. The lint in the air contains both short and long fibers, the greatest percentage by number being the short fibers, but the greatest percentage in weight being the long fibers. From the tests made it appears that the dust-lint mixture made up entirely of long fibers affects the filter performance characteristics in substantially the same manner as a similar dust-lint mixture made up of short and long fibers of the same ratio as found in lint removed from filters. For this reason the long fibers which are more easily prepared should be satisfactory for the comparative rating of filters.

2. The percentage by weight of lint to dust in air has not been definitely determined, and before selecting any fixed standard mixture for rating of filters more study should be given to this point. For those filters, however, which are affected by lint the relative ratings probably would be substantially the same regardless of the percentage of lint used.

3. Lint in air has a dominating influence on the life and dust holding capacity of some filters. With three of the four filters tested the addition of 10 per cent by weight of long fiber lint to the test mixture reduced the life to less than 20 per cent of that determined with no lint in the mixture. Additional lint up to 20 per cent showed relatively little further reduction in life.

4. Lint in air tends to increase the arrestance of most air filters slightly. With all filters tested increasing percentages of lint by weight resulted in increasing arrestances, partly due to the increased dust eliminating efficiency of the media when containing lint deposits, and partly due to the fact that the filters were practically 100 per cent efficient in removing lint.

5. The effect of lint on the performance characteristics of filters appears to be greater for that type in which the filter capacity depends upon the distribution of dust throughout its depth. For this type of filter the effect of lint is increased when some section is of such construction as to trap the lint and cause abnormally high localized pressure drops.

6. A filter which is designed with large surface area for the purpose of holding the dust on the surface of the filter media may not be seriously affected in its performance characteristics by lint in the air, as there is a large exposed surface area for catching the lint. Furthermore, the lint may be of the same general type of material as used for the filter media, thus having the effect of increasing the thickness of the media without seriously interfering with its performance.

7. Since in practice many filters are called upon to eliminate rather large percentages of lint from the air, and since lint in

Table 3—Distribution of Long Lint Fibers in Filters after Laboratory Tests

Filter	Distribution of Lint in Filter	Amount Lint Passed Through Filter
A-1	Lint deposited throughout filter with some of the fine mesh openings at exit of filter completely plugged	None
B-3	Lint matted across inlet surface of filter—practically all lint removed in first ½ in. layer of filtering media	None
C	Majority of lint deposited at entrances to first and second passes—heaviest deposit at second pass with some cells entirely plugged	Trace
D	Lint deposited between fingers with space plugged practically solid 4 to 5 in. back from exit side of filter	None

Table 2—Effect of Dust-Lint Ratio on Filter Life and Arrestance

Type of Lint	Per Cent by Weight of Lint in Mixture	Filter *A*-1		Filter *B*-3		Filter *C*		Filter *D*	
		Arrestance in Per Cent	Ratio[a] $\frac{A}{B}$ in Per Cent	Arrestance in Per Cent	Ratio[a] $\frac{A}{B}$ in Per Cent	Arrestance in Per Cent	Ratio[a] $\frac{A}{B}$ in Per Cent	Arrestance in Per Cent	Ratio[a] $\frac{A}{B}$ in Per Cent
Short Fiber Lint	0	81.0	100.0	87.2	100.0	70.5	100.0	92.4	100.0
	5	83.7	83.4	89.5	68.9	76.5	66.1	93.0	96.1
	10	84.7	55.6	88.7 89.6	50.2 53.7	76.8	62.4	90.6 93.5	91.0 90.4
	15	85.8	56.0	89.5	49.3	76.6	54.8	93.7	82.0
	20	86.3	55.4	89.4	43.2	78.3	37.4	93.4	64.8
Long Fiber Lint	0	81.0	100.0	87.2	100.0	70.5	100.0	92.4	100.0
	5	85.7	37.9	91.7	26.6	71.6	13.9	93.0	105.0
	10	88.7	19.7	92.0	16.0	70.6	7.8	93.4	91.7
	15	86.4	15.2	.....	.....	.....	.....	.....	.....
	20	88.8	13.6	93.2	12.4	76.5	5.2	95.5	83.3
14 per cent short fiber 86 per cent long fiber	10	86.5	21.2	90.7	16.0	.....	.....	.....	.....

[a] A = Filter life in hours when tested on dust-lint mixture.
B = Filter life in hours when tested on dust mixture alone.

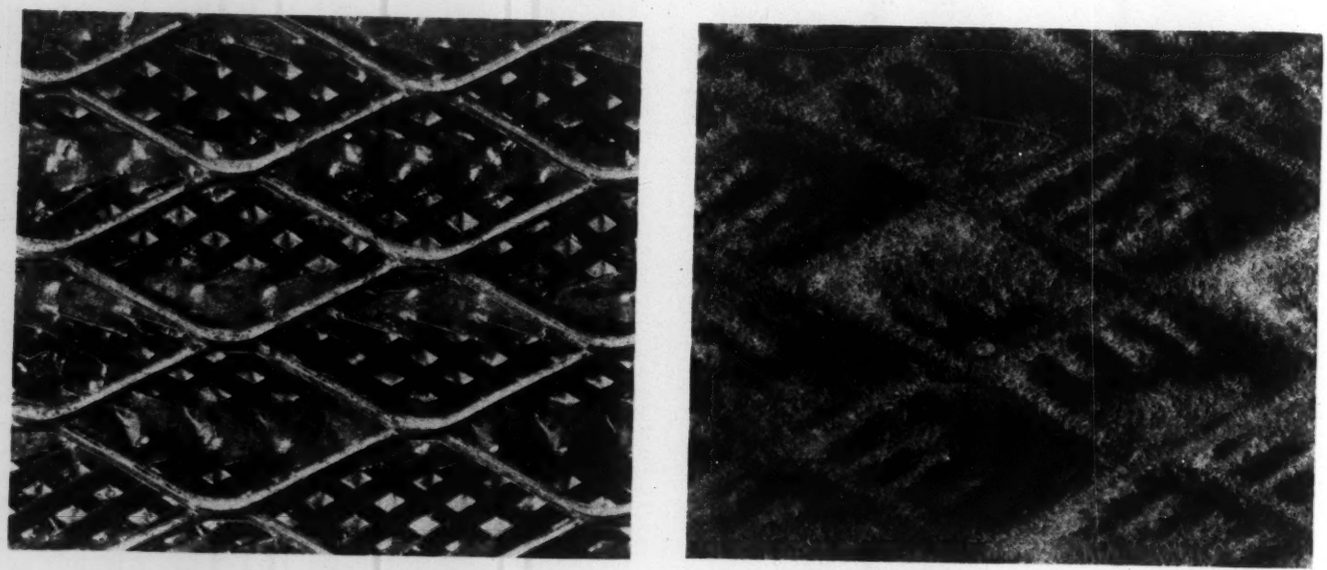

Fig. 8—Filter *A-1* before and after laboratory lint test

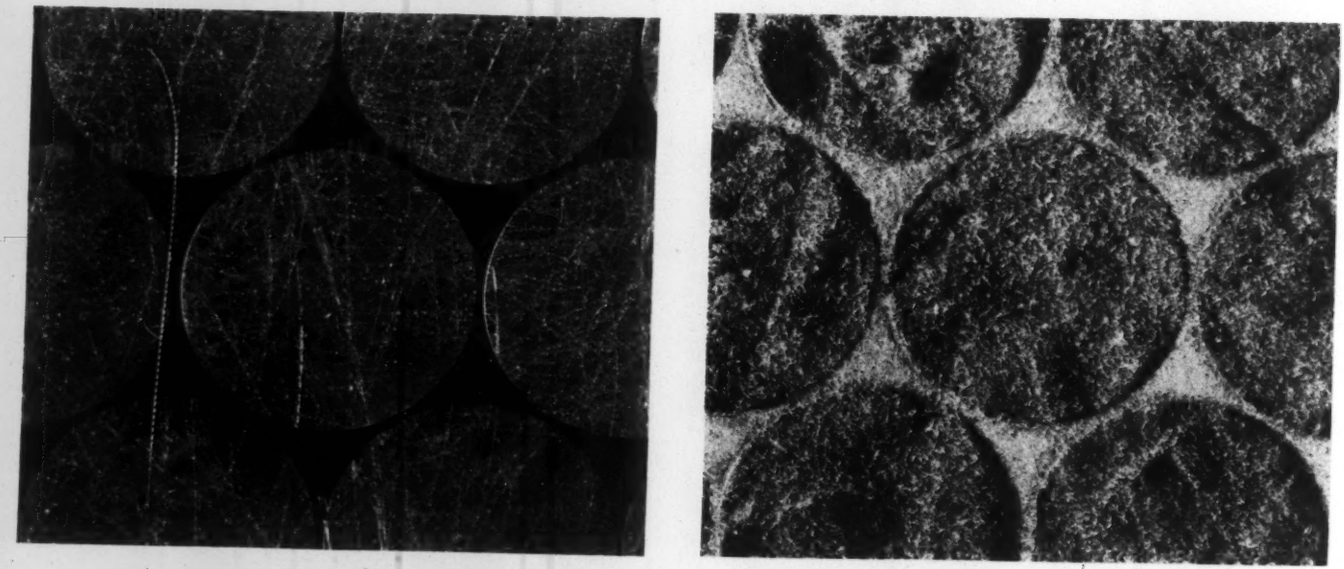

Fig. 9—Filter *B-3* before and after laboratory lint test

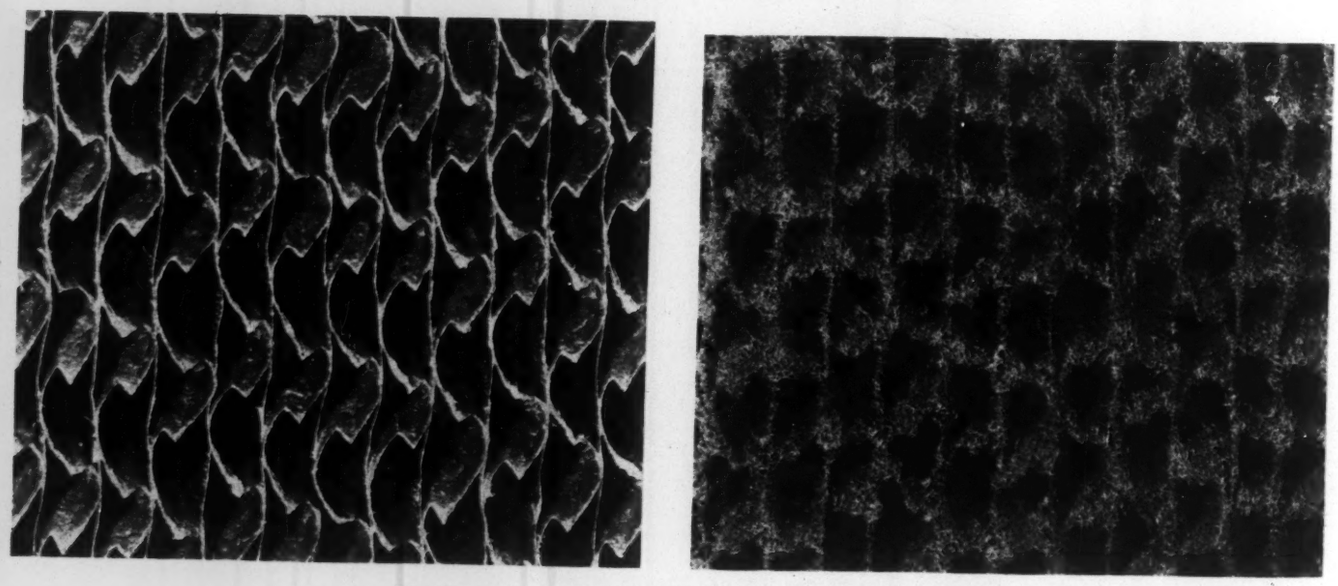

Fig. 10—Filter *C* before and after laboratory lint test

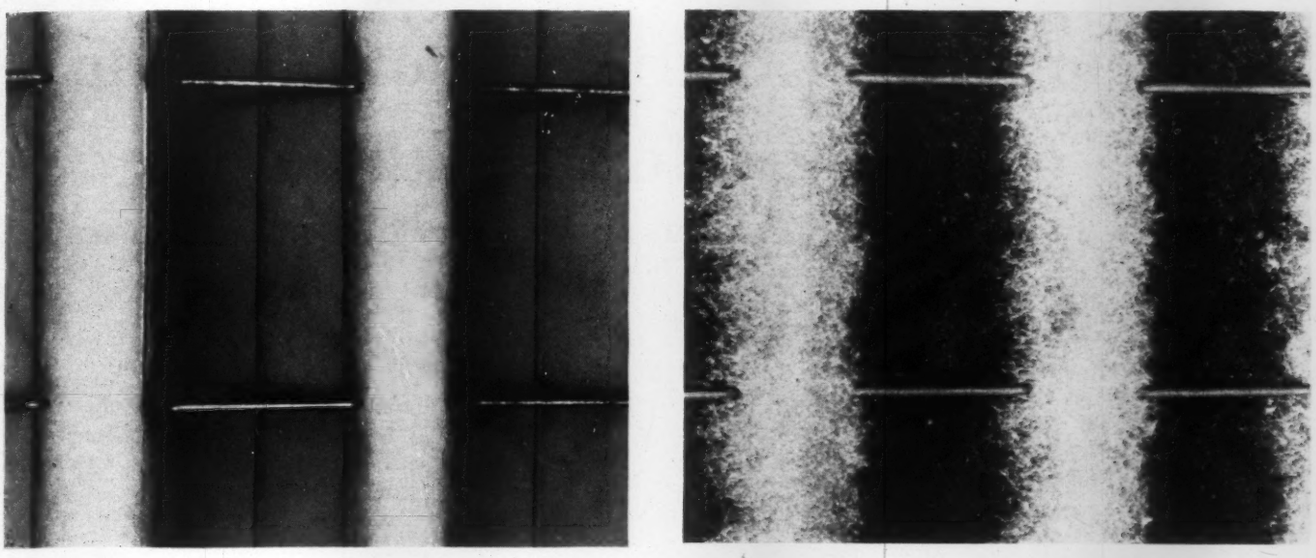

Fig. 11—Filter *D* before and after laboratory lint test

the air has a dominating influence upon the filter performance characteristics, lint should be considered as an element in the standard dust used for rating air filters.

These tests were conducted for the purpose of studying the characteristics of different types of filters when tested with varying mixtures of dust and lint, and not for the purpose of comparing the different filters used. Any attempts to compare the relative merits of the filters would be misleading. It should not be construed that those filters which showed the greatest reduction in life with increasing percentages of lint were also those with the shortest life in hours, as that was not always the case. The filters used were selected because they were typical of their classifications, and it should not be considered that they are necessarily superior to other filters within their classifications.

The authors wish to acknowledge the cooperation of F. C. Houghten, Director, ASHVE Research Laboratory; and the Technical Advisory Committee on Air Cleaning and Atmospheric Impurities. It is also gratifying to note that the manufacturers of the various types of filters used were generous in the supply of any materials requested, and gave their full cooperation to make the program possible.

Chain Stores Spent 1¼ Millions on Modernization Program

Maintaining their lead in the use of retail air conditioning units and employing many of the newly-developed attractive building materials, the nation's chain store operators in 1939 set a new peak for store modernization with expenditures of $126,159,914, according to figures compiled by *Chain Store Age*.

Led by the variety and department stores, the chains exceeded the 1938 figures by 12.2 per cent and surpassed the previous record, breaking the all-time high of 1937 by 1.3 per cent. The figures do not include sums spent by landlords preparing properties for chain store occupancy, which are estimated at 20 per cent of the chains' own total, or approximately $24,225,000.

Based on direct reports from chain companies, according to *Chain Store Age*, the figures indicate an acceleration in increase of modernization of stores, rather than expansion in number of stores operated. New units opened in 1939 equal 4.5 per cent of the total, which includes relocations and replacements. With the total number of chain stores in operation in 1939 somewhat smaller than 1938, the number of stores remodelled is equal to 10.7 per cent of the total in operation.

The survey further points out that the chains' expenditures for modernization have, with one exception, consistently increased since 1933, when the total spent was $32,995,000, and that in each of the past three years chains have spent more than $110,000,000 for this purpose.

In construction details, with few exceptions the chains are forsaking standardization for individuality in store design. The effect of the two World's Fairs can be seen in the increased use of translucent lighting. A great increase in the use of all types of structural and ornamental glass, such as glastone, vitrolite, vitrolux and all-glass doors, is noted. In the case of asphalt tile used as floor covering, a grease proof variety has been developed for space where grease and oil will be encountered.

Expenditures for air conditioning totaled $7,578,357, an impressive figure, the survey states, in view of big expenditures in preceding years for installations. Although 8.2 per cent lower than the 1938 figure, 13 per cent of all new and remodelled stores in 1939 were equipped with air conditioning as compared to 12 per cent last year. In six leading fields—department-variety, drug, grocery, restaurant, shoe and apparel—9.1 per cent of all stores in operation have installations, and, according to the survey, the chains are convinced of the value of air conditioning and present a tremendous field for installations in the future.

In order of expenditures, the various types of chain store companies spent the following for modernization in 1939: variety-department store, $47,596,197, an increase of 6 per cent over 1938; grocery, $28,320,553, up 64 per cent, by far the largest increase; drug, $7,977,032, up 4 per cent; apparel, $9,397,350, a decrease of 17 per cent; restaurant, $8,818,220, up 42 per cent; shoe, $3,584,562, an increase of 31 per cent; and all other types, $20,466,000, a decrease of 10 per cent.

Thermal Test Coefficients of Aluminum Insulation for Buildings

By Gordon B. Wilkes,* (*MEMBER*) Cambridge, Mass.; F. G. Hechler,** and E. R. Queer† (*MEMBER*), State College, Pa.

ALTHOUGH the principle of reflective insulation has been known for a long time, it was not until 1927 that thin sheets of aluminum foil were first used commercially as insulation. Because the basic principle of reflective insulation differs from that of other types and because of the relative newness of its application there is some confusion regarding its properties and use, and there are relatively few data in the literature giving the heat transmission for construction using this material.

Brightness

The term *brightness* as applied to reflective insulation ordinarily means the effect of the reflection of light on the eye. Brightness is a photometric term dealing with the measure of light (luminous power) emitted from a surface. It is synonymous with lustrous, sparkling, gleaming, flashing, glittering, or glistening. The wave lengths of the visible spectrum of light extend from approximately 0.4 to 0.7 μ (microns). The wave-length connected with heat radiation from a source at room temperature is approximately 10.0 μ, which is far removed from the visible range. If there were a definite relation between the reflectivity of light and this long wave-length radiation, then the reflectivity for infrared could be judged by means of the eye and visible reflectivity. Unfortunately, there is no such definite relation. It has been stated[1] that "a piece of aluminum may have high reflectivity for visible light and low reflectivity for infrared radiation, or it may have only fair reflectivity for light and be an excellent reflector of infrared radiation, depending on the presence or absence of surface films. It may also be a good reflector for both kinds of radiation."

A mirror, consisting of glass with a *silvered* surface on the back of the glass, is an excellent reflector of light but it is a very poor reflector of infrared radiation corresponding to room temperature. In fact, such a mirror would have about the same reflectivity for infrared as a heavy coating of black paint.

With this in view, it is obviously impossible to judge the infrared reflectivity or emissivity of a surface by its appearance to the eye. Consequently, in a discussion of reflective surfaces for building insulation, the term *brightness* has no specific meaning. The terms *emissivity* or *reflectivity* definitely define the radiating or reflecting power of a surface and values may be determined directly for the long wave-length radiation corresponding to room temperatures.

Permanence

Since the insulating value of reflective surfaces is due largely to the nature of the surface, it is only natural that inquiry should be made as to the permanence of these surfaces. The following quotation from a previous paper[2] will show some of the reasons why the life of aluminum foil insulation need not be doubted when properly installed under normal conditions.

Aluminum foil has now been in use for a sufficient number of years to establish the permanence of the surface when properly installed under suitable conditions. The following examples are taken from sources that are believed to be authentic:

1. Aluminum-foil-insulated house in Skovshoved, Denmark. This house was built and insulated in 1927. Samples of the foil were removed in October, 1935, by engineers from the Tecnolgisk Institute, Copenhagen. The official report states: "We can testify that the brightness of the aluminum foil was unchanged in comparison to new foil of the same kind."

2. Aluminum-foil-insulated provision chambers of the motorship *Leverkusen,* fitted out in May, 1928. In January, 1934, samples of this foil were removed by representatives of Lloyd's Register of Shipping, Hamburg; they reported: "The general impression gained as a result of the examination made is that the insulation examined by us is in exactly the same condition as it was five years ago when built into the vessel."

3. Aluminum-foil-covered cardboard taken from foil-insulated dry-ice cabinet. It was exposed to the weather on a beach at Coney Island from September, 1934, to April, 1935. The emissivity of the foil removed from this cabinet was 0.04.[3]

4. Aluminum foil suspended vertically in laboratory for three years and measured with accumulated dust and fume. The emissivity was 0.05.[4]

The following examples give some of the author's personal experience over a period of 10 years with regard to the permanence of aluminum foil insulation:

1. Aluminum-foil-insulated residence, Wellesley Hills, Mass., built and insulated in 1933. The author personally removed samples of this insulation from the underside of the roof in June, 1938. The samples appeared in perfect condition, and the average emissivity of the four samples removed was 0.054 as compared with 0.045 for new foil.

2. Aluminum foil after two-year exposure to salt spray and moisture on underside of roof of log boat house in Newington, N. H. The foil was spotted with salt that had been left on the foil by evaporation of the salt spray. The emissivity was found to be 0.10.

3. Aluminum foil exposed in a vertical position since 1929 to the dust and fumes in the Heat Measurements Laboratory, M.I.T. Samples of this foil have been removed from time to time and the emissivity has been determined. Over a period of 10 years no appreciable change in emissivity has been found.

4. Aluminum foil insulation placed over ceiling in attic of residence in Newton Centre, Mass. After three years no appreciable change could be noted.

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[1]Some Reflection and Radiation Characteristics of Aluminum, by C. S. Taylor, and J. D. Edwards. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, January 1939, p. 59.)

For presentation at the 46th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Cleveland, Ohio, January, 1940.

[2]Reflective Insulation, by G. B. Wilkes. (*Industrial and Engineering Chemistry*, 31:832, July, 1939.)

[3, 4]Loc. Cit. Note 1.

5. Aluminum foil insulation in ceiling of a cellar with no covering of any kind. After three-year exposure this foil appeared in perfect condition except over the laundry tubs where soap had apparently come in contact with the foil and attacked the surface in spots. This cellar was very damp every summer.

6. Hundreds of samples of aluminum foil have been stored in the laboratory for various periods of time up to 10 years with no visible signs of deterioration of the surface.

There are, however, certain conditions, that may seriously affect the heat resisting properties of aluminum foil. Alkalies attack aluminum readily and the foil should always be protected from direct contact with wet plaster. If prolonged exposure to moisture is expected, it is possible to coat aluminum foil with a thin transparent lacquer as a protective agent. This coating, however, should only be applied by the manufacturer as an ordinary coat of transparent lacquer will usually ruin the reflective properties of the aluminum for infrared radiation although it will still appear bright to the eye and will continue to be an effective reflector of visible radiation.

A heavy coating of dust on a surface of aluminum will certainly reduce the reflectivity materially. In ordinary building insulation, this is not likely to occur on vertical walls nor on the underside of sloping and horizontal sheets. On the upper side of sloping or horizontal surfaces it would be possible for a heavy dust layer to collect if there were sufficient dust available, which is unlikely in most cases. If a sheet of building paper is placed above the top layer of foil in these sloping and horizontal positions, even this possibility would be minimized. A light coating of dust, while affecting the visible reflectivity considerably, has only a minor effect on the infrared reflectivity.

Heat Transmission Tests on Roof and Wall Sections with Aluminum Insulation

The insulation used in these tests was of two kinds. One consisted of a sheet of kraft paper with aluminum foil cemented to one side only (Type I) while the other had aluminum foil on both sides of the paper (Type II).

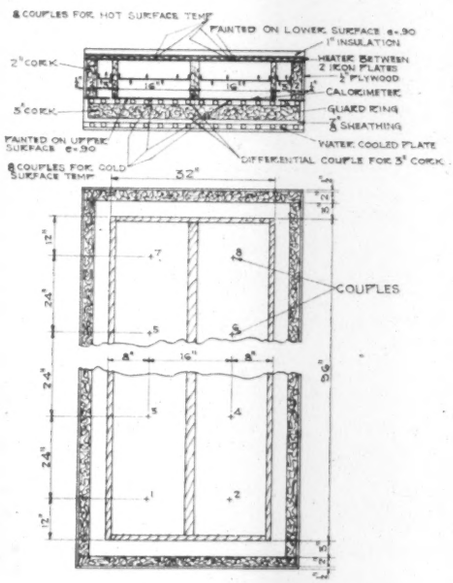


Fig. 1—Diagram of guarded plate calorimeter

The material was purchased in the open market and was representative of that now available to the consumer. Prior to making the heat-transfer tests, samples were taken from each roll of material and emissivity measurements were made with a radiometer. The values ranged from 0.045 to 0.053 with an average value of 0.05 for a temperature of 212 F.

Roof Tests[5]

The essential parts of the apparatus used in the calorimeter tests have been previously described.[6] Important improvements were made, however, for the purpose of the tests which include the following:

1. A 5-in. water-cooled guard ring was installed entirely around the calorimeter.

2. A water-cooled plate was placed on the back, separated from the calorimeter by 3 in. of corkboard. This minimized the gain or loss of heat from the calorimeter and made this correction very small.

3. The air space in the guard ring was of the same construction as in the test area.

4. An electrically-heated plate, covering the calorimeter and guard ring, was installed on the warmer side of the air space as shown in Fig. 1.

The results of these calorimeter tests (Table 1) are shown best in Fig. 2. Each point indicates an actual test value which is the average of two or more runs which checked better than 1 per cent. It required approximately 24 hours to establish thermal equilibrium after the position or temperature condition was changed.

The calorimeter tests, as shown in Fig. 2, confirm previous evidence that the rate of heat transfer across air spaces faced with reflective surfaces is greatly affected by the position and direction of heat flow. In the case of a flat roof, the conductance of an 8-in. air space with a single layer of reflective insulation placed in the middle (temperature difference being 25 F) is 0.087 Btu per hour per square foot per degree Fahrenheit when the heat flow is downward as compared with 0.238 with the heat flow upward. In other words, under winter conditions the conductance is equivalent to about

[5]The emissivity and roof tests were made at Massachusetts Institute of Technology under the supervision of Professor Wilkes.

[6]Radiation and Convection Across Spaces in Frame Construction, G. B. Wilkes, and C. M. F. Peterson. (ASHVE TRANSACTIONS, Vol. 43, 1937, p. 351.)

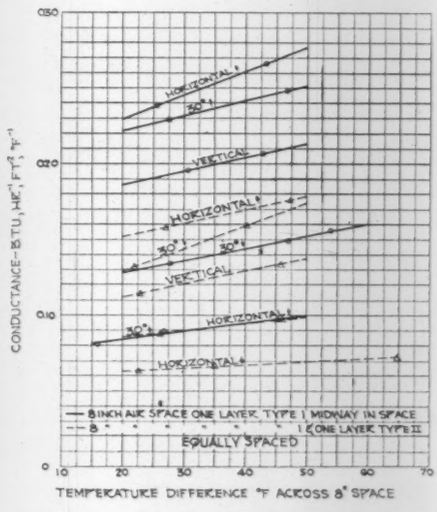


Fig. 2—Results of calorimeter tests

Table 1—Results of Calorimeter Tests

Position	Warm Surface F	Cold Surface F	Temp. Difference F	Conductance (Test)	Calculated U_a
Type II Insulation Making Two 4-in. Air Spaces. Installed as in Construction Nos. 1, 2, and 3 (Fig. 3)					
Horizontal	98.6	82.4	16.2	0.081	0.066
Heat down	107.0	80.2	26.8	0.089	0.070
	125.2	79.8	45.4	0.097	0.075
30 deg slope	107.5	79.5	28.0	0.135	0.105
Heat down	127.6	80.5	47.1	0.149	0.114
	132.0	78.0	54.0	0.156	0.118
Vertical	110.6	79.7	30.9	0.196	0.124
	125.0	82.0	43.0	0.207	0.129
30 deg slope	109.2	81.5	27.7	0.229	0.156
Heat up	129.3	82.3	47.0	0.248	0.165
Horizontal	105.7	80.1	25.6	0.238	0.140
Heat up	126.1	82.7	43.4	0.266	0.149
Types I and II Insulation Making Three 2.7-in. Air Spaces. Installed as in Construction Nos. 4, 5, and 6 (Fig. 3)					
Horizontal	104.8	82.1	22.7	0.063	0.053
Heat down	115.1	80.0	35.1	0.067	0.056
	145.3	80.5	64.8	0.072	0.059
30 deg slope	106.6	80.3	26.3	0.088	0.075
Heat down	128.2	82.0	46.2	0.097	0.081
Vertical	100.7	77.7	23.0	0.114	0.086
	121.7	76.0	45.7	0.134	0.096
30 deg slope	99.1	77.0	22.1	0.133	0.105
Heat up	118.2	78.1	40.1	0.159	0.120
Horizontal	105.3	78.1	27.2	0.158	0.108
Heat up	130.8	83.1	47.7	0.176	0.116

[a]The calculated U value is based on the following values taken from The Guide, 1939:
Horizontal—flat roof, page 112, No. 6, 1½-in. roof deck, metal lath and plaster—uninsulated — $U = 0.26$
30 deg-sloping roof, page 114, No. 6, asphalt shingles, metal lath and plaster—uninsulated — $U = 0.34$
Vertical-frame wall, page 107, No. 65(B), metal lath and plaster—uninsulated — $U = 0.26$
Ordinary air space — $C = 1.10$

1.2 in. of conventional insulation but under summer conditions it is equivalent to more than 3 in. of conventional insulation.

Fig. 2 also shows the variation of the conductance with temperature difference, indicating in general a very definite increase with increase of temperature difference.

This type of apparatus is capable of considerable precision as may be seen from the data and sample calculation. All of the factors used in calculating the conductance value may be measured with sufficient precision so that the error should certainly be less than 1 per cent. Separate runs can easily be made to check within 1 per cent and usually within ½ of 1 per cent. Of course, this merely means that results with this type of apparatus can be duplicated. Every precaution has been taken to insure the absolute value of the conductance that could reasonably be installed.

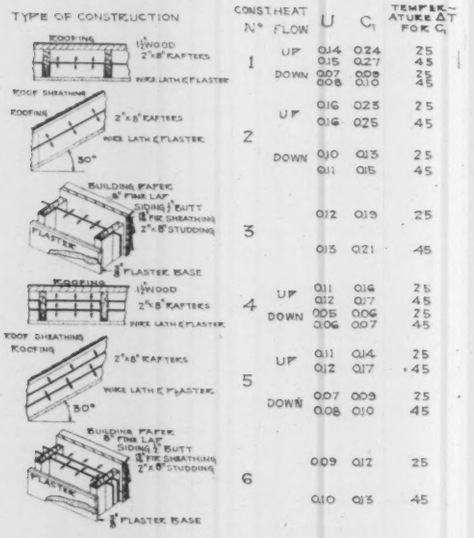


Fig. 3—Roof and wall coefficients with aluminum insulation

Data and Calculation of Sample Run. Horizontal—heat downward, Types I and II in 8-in. space.

Couple No.[a]	Calorimeter Temp. mv	Calorimeter Temp. F	Heater Temp. mv	Heater Temp. F	Calorimeter Δt Time	Calorimeter Δt mv
1	1.108	80.05	1.932	113.90	0	0.102
2	1.102	79.78	1.929	113.79	1	0.102
3	1.103	79.82	1.968	115.34	2	0.102
4	1.099	79.64	1.979	115.79	3	0.102
5	1.102	79.78	1.991	116.28	4	0.102
6	1.104	79.87	2.015	117.25	5	0.102
7	1.108	80.05	1.936	114.06	6	0.103
8	1.105	79.91	1.957	114.89	7	0.102
					8	0.102
					9	0.103
					10	0.102
Avg		79.86		115.16		0.1022

[a]For location see Fig. 1.

Rise in temperature of calorimeter water
0.1022 mv (five couples in series) ..... 0.901 F
Weight of calorimeter water ..... 55.86 lb per hour
Uncorrected heat absorbed by calorimeter .. 50.2 Btu per hour
Temperature difference across 3-in. cork back ..... 0.13 F
Heat loss from calorimeter through cork back ..... 0.3 Btu per hour
Corrected heat absorbed by calorimeter .... 50.5 Btu per hour
Temperature difference across 8-in. space .. 35.30 F
Area of calorimeter ..... 21.3 sq ft

$$\text{Conductance of space} = \frac{50.5}{21.3 \times 35.30} = 0.0672 \text{ Btu per hour per square foot per degree Fahrenheit}$$

Fig. 3 shows the results reduced to a form in which they are usually used. The U values shown are for an inside surface coefficient of 1.65 and an outside coefficient of 6.00 corresponding to a 15 mph wind.

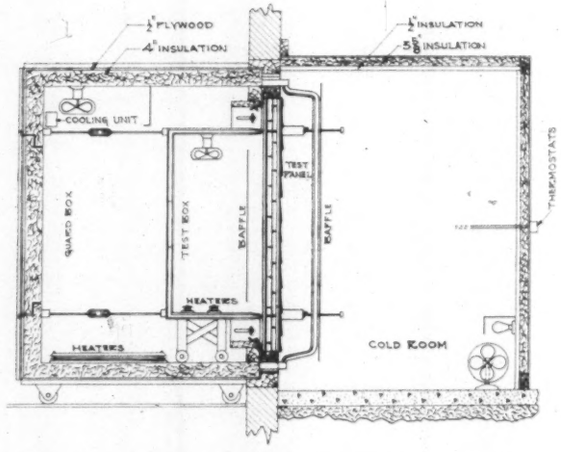


Fig. 4—Guarded hot box assembly with test panel in position

Wall Tests[7]

The tests on vertical wall sections using 2x4 studs were made in a large guarded hot-box apparatus designed for sections 67⅝ in. x 67 in. in area. A sketch of the equipment with a wall in position ready for test is shown in Fig. 4. The test box covered a 4 ft x 4 ft area at the center of the wall under test. The following features may be noted:

1. The heat to the boxes was supplied by 440-volt strip heaters located at the bottom of each box and shielded. The heaters were operated on low voltage a-c to keep radiant heat at a minimum.
2. Sensitive bimetallic thermostats controlled a small portion of the total heat input to maintain the temperatures constant within ± 0.2 F.
3. The inner and outer surfaces of the test box were covered with 16-oz copper sheets, painted black, thermally and electrically insulated from each other. Thermocouples were soldered to both surfaces and used for balancing the temperatures in the test box and guard box.
4. The power input to the test box was measured with a portable standard watt-hour meter.
5. To permit testing with the warm side of the panel at temperatures below normal room temperature a small water-cooled automobile heater was installed near the top of the guard box.
6. Access doors were provided at the back of the guard box and the test box to permit inspection and adjustment when installing a test panel.
7. Small circulating fans were installed in the test box, the guard box, and the cold room. It was found that those in the test box and guard box were not needed to give satisfactory temperature distribution and they were not operated. The fan in the cold room was run at low speed to maintain a slow air movement.
8. Baffles or shields were placed near the test wall on each side.

Fig. 5 shows the construction of the test wall and the method of taking it apart for the installation of the insulation in different ways. The 4 ft x 4 ft test box covered three stud spaces on the panel. To limit the vertical height in the stud spaces to 4 ft, in order to separate the test and guard areas, thin strips of plywood were used to block off these spaces, as shown. Thermocouples were attached to both the hot and cold sides; other thermocouples were distributed throughout the wall, making it possible to determine the conductances of all parts of the wall.

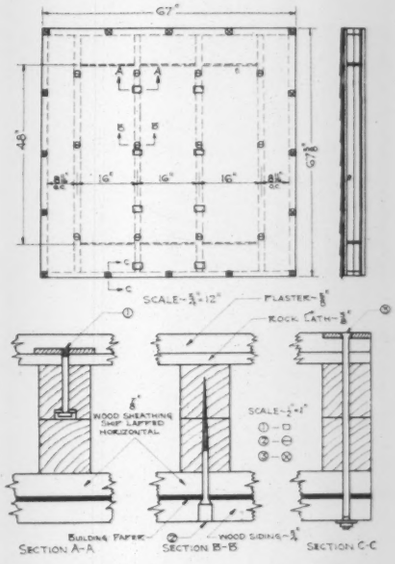


Fig. 5—Construction of wall test panel

The results of the guarded hot-box tests are shown in Table 2. Air temperatures in the tests at 0 and 70 were used to simulate those encountered in heating plant design; 30 and 70 are an average winter condition; 70 and 100 are a maximum summer condition. It required about 14 hours to establish thermal equilibrium for each test and equilibrium was maintained for 10 hours.

Fig. 6 shows the results reduced to the form in which they are most frequently used. The insulation applied to Wall No. 2 had a row of ⅛-in. holes in one stud space on a vertical line at 12-in. intervals through the insulation. Wall No. 2a contained the same type of insulation as No. 2, but without holes in the material. Wall No. 5 had Type I insulation looped in between the studs similar to Wall No. 2, Fig. 6. A test was made on Wall No. 2a with 140 F on the warm side and 70 F on the cold side to show that for reflective insulation nothing is gained by testing the material at high temperatures. The tests were made during the summer when the humidity was high. Before making the second test on Wall No. 2a (0 and 70 F) the test-box temperature was dropped to 50 F with 0 F on the cold side for two days. Under these conditions moisture might be expected to collect on the

Table 2—Results of the Guarded Hot-Box Tests

	Wall No.																										
	1			2			2a					3			4			5a									
Heat, Btu per sq ft per hour	13.25	7.64	6.15	7.99	4.45	3.21	7.66	7.74	4.21	3.26	8.95	9.47	5.44	4.41	5.85	3.19	2.37	9.20	5.20	4.06							
Hot Air, F	69.9	70.3	100.3	70.0	70.4	100.3	70.2	70.3	70.3	100.4	140.0	70.1	70.3	100.3	70.1	70.3	100.1	69.7	69.9	100.1							
Hot surface, F	59.3	63.9	95.5	64.1	67.3	98.0	64.4	64.4	67.2	98.2	135.1	63.5	66.1	97.1	65.9	67.9	98.4	62.8	65.8	97.2							
Plaster base, F	53.6	60.4	92.4	61.1	65.7	96.7	61.4	61.6	65.7	97.0	131.9	59.7	63.8	95.2	63.8	66.6	97.3	58.9	63.7	95.4							
(1) Aluminum surface, F				46.4	54.7	88.0	45.2	44.4	54.6	88.2	113.0	55.4	61.5	93.9	49.5	57.8	90.7	50.8	59.1	92.3							
(2) Aluminum surface, F															35.2	48.9	83.7										
Sheathing, F	41.1	53.1	86.9	25.9	42.9	78.8	25.8	24.8	43.0	79.2	93.1	31.4	46.8	81.6	19.3	39.2	76.3	28.1	44.8	80.4							
Cold surface, F	12.3	36.5	74.2	8.4	33.6	72.2	8.4	7.2	33.7	72.6	75.9	9.5	34.7	72.2	6.3	32.5	71.5	7.8	34.0	72.6							
Cold air, F	0.0	30.1	70.3	0.0	29.9	70.1	+0.2	−0.6	30.3	70.5	70.5	−0.6	29.7	69.4	−0.3	30.0	70.0	−0.8	30.0	70.2							
U at 15 mph. (calculated)	0.23	0.23	0.24	0.13	0.12	0.11	0.12	0.12	0.12	0.12	0.14	0.15	0.15	0.16	0.09	0.08	0.08	0.15	0.15	0.15							
U (test)	0.19	0.19	0.21	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.13	0.13	0.13	0.14	0.08	0.08	0.08	0.13	0.13	0.14							
C, surface to surface	0.28	0.28	0.29	0.14	0.13	0.12	0.14	0.14	0.13	0.13	0.15	0.18	0.17	0.18	0.10	0.09	0.09	0.17	0.16	0.17							
f, inside	1.25	1.19	1.28	1.35	1.44	1.40	1.32	1.31	1.36	1.48	1.83	1.43	1.30	1.38	1.39	1.33	1.39	1.33	1.27	1.40							
C, plaster and base	2.32	2.18	1.98	2.66	2.78	2.47	2.55	2.76	2.81	2.72	2.80	2.49	2.37	2.32	2.79	2.45	2.16	2.36	2.48	2.26							
C, plaster base to Type I												2.20	2.37	3.39													
C, air space, e-eff. = 0.82	1.06	1.05	1.12															1.14	1.13	1.31							
C, (1) aluminum air space				0.54	0.40	0.37	0.47	0.45	0.38	0.37	0.47	0.40	0.37	0.36	0.41	0.36	0.36	0.41	0.36	0.34							
C, (2) aluminum air space				0.39	0.38	0.35	0.40	0.40	0.36	0.36	0.45				0.41	0.36	0.34										
C, (3) aluminum air space															0.37	0.33	0.32										
C, lumber	0.46	0.46	0.48	0.46	0.48	0.49	0.44	0.44	0.45	0.49	0.52	0.43	0.45	0.47	0.45	0.48	0.49	0.45	0.48	0.52							
f, outside	1.08	1.19	1.58	0.95	1.20	1.53	0.93	0.99	1.24	1.55	1.66	0.94	1.09	1.58	0.89	1.28	1.58	1.07	1.30	1.69							
C, plaster base to sheathing	1.06	1.05	1.12	0.23	0.20	0.18	0.22	0.21	0.19	0.18	0.23	0.34	0.32	0.33	0.13	0.12	0.11	0.30	0.28	0.27							

[a] Wall No. 5—same insulation as Wall No. 3, except that it was looped between the studs, forming a 1-in. air space.

[7] The wall tests were made by the Engineering Experiment Station, Pennsylvania State College, under the supervision of Professors F. G. Hechler and E. R. Queer.

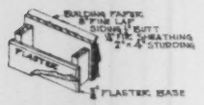
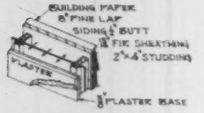
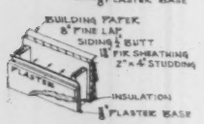
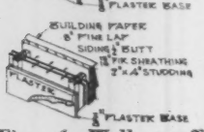
TYPE OF WALL	WALL N°	C	U	C_1	AIR TEMPERATURES	
	1	0.28	0.25	1.06	70	0
		0.28	0.25	1.05	70	30
		0.28	0.24	1.12	70	100
	2a	0.14	0.12	0.21	70	0
		0.13	0.12	0.19	70	30
		0.13	0.12	0.18	70	100
	3	0.18	0.15	0.34	70	0
		0.17	0.15	0.32	70	30
		0.18	0.16	0.33	70	100
	4	0.10	0.09	0.13	70	0
		0.09	0.08	0.12	70	30
		0.09	0.08	0.11	70	100

Fig. 6—Wall coefficients with aluminum insulation

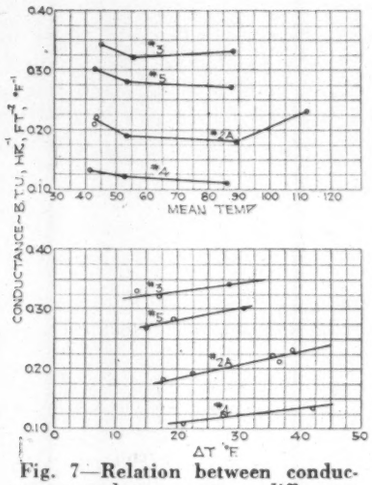


Fig. 7—Relation between conductance and temperature difference

insulation; however, the results of this test, as well as those of other tests, gave no indication that condensation was occurring. Some variations took place in the conductance of the individual parts of the wall. This was caused by variations in the small measured temperature differences.

For most insulating materials the conductance increases with mean temperature. That this is not the case for reflective insulation is shown in Fig. 7. However, there is a well defined relation between conductance and temperature difference. In general the curves in Fig. 7 agree with the corresponding curves in Fig. 2.

There are several interesting points in the data to which attention is invited. The plaster-side surface coefficient for a 70 F air temperature for natural convection is 1.33. At one time THE GUIDE recommended a value of 1.34 but the present value is 1.65. This difference is practically insignificant for the average wall. An average conductance of 2.54 was obtained for the plaster and base for an inside air temperature of 70 F. In Wall No. 3 the insulation was not attached directly to the plaster base, but was stretched tightly across the studs which produced a certain amount of resistance to heat flow between the plaster base and paper. This resistance was included in the value for *C* of Wall No. 3, Fig. 6. The resistance of about 0.43 obtained in these tests agrees closely with that given in a previously published paper.[8]

Summary

1. When the roof tests were made in the various positions, one test of each application of insulation was made in a vertical position. An inspection of Figs. 3 and 6 shows the excellent agreement obtained in the results by the two different methods of test. These values confirm the reliability of the guard plate calorimeter as a method of making heat transmission tests and establish the validity of the results obtained by two independent methods.

2. It should be noted that the results of these tests again confirm the fact that the conductance of an air space faced with a reflective surface varies with the temperature difference and, as shown in these experiments, there appears to be no relation with mean temperature. In the case of reflective insulation the principal mode of heat transfer is by convection and only a small amount is transferred by radiation. The heat transfer by convection varies as the 5/4 power of the temperature difference. Consequently the smaller the temperature difference the lower the conductance value of an air space containing reflective insulation. This fact is borne out by the data and in all cases the values at 25 F difference are lower than those for 45 F difference. The 25 F difference is an extreme summer condition and the 45 F difference is an extreme winter condition.

3. For reflective insulation orientation must be considered. An unusually low heat-transfer value is obtained with the heat flowing down. This is particularly striking in the horizontal positions, Constructions Nos. 1 and 4, Fig. 3. In these cases the major portion of the heat transfer is by conduction while radiation and convection are a minimum. In some instances the reflective insulated structures are vented for summer conditions. However, the vents should be closed for the heating season.

4. Insulation is usually added to a structure to obtain fuel savings and produce comfort to the occupants of the building. The comfort factor is more important in the summer than winter, since most heating systems have sufficient capacity to produce comfort. Since reflective insulation performs most effectively with the heat flowing down, as it does in the summer, this insulation is particularly effective in retarding summer heat influx through roofs into top floor living quarters.

Acknowledgment

The authors wish to acknowledge the assistance given by Prof. C. M. F. Peterson and L. R. Vianey of the Heat Measurements Laboratory, Massachusetts Institute of Technology; and W. H. Ness, research assistant in engineering research, Engineering Experiment Station, The Pennsylvania State College, in making these tests.

[8]Heat Loss through Wall Construction, by Alf Kolfaath. (ASHVE JOURNAL, September, 1924, p. 627.)

Duke University College of Engineering

In accordance with a resolution adopted by the Board of Trustees of Duke University, the Division of Engineering, which was administered as part of Trinity College, was reorganized recently into the College of Engineering of Duke University. W. H. Hall, professor of civil engineering and chairman of the division of engineering, has been appointed Dean of Engineering. Three courses in engineering, civil, electrical, and mechanical are offered. The full time teaching staff consists of four men in each of the civil and electrical engineering departments, and five men in the mechanical engineering department.

Prof. F. J. Reed, mechanical engineering department, is a charter member of ASHVE Carolina Chapter, and a member of its membership and entertainment committees.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS *is located*

ASHVE Committee on Research

Twenty-First Annual Report

1939

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THE Committee on Research closed its 1939 activity after an eminently successful year. Three meetings of the entire Committee were held, two during the Annual Meeting in January and one during the Semi-Annual Meeting in July. At these meetings the Committee organized, prepared and directed the operations under its budget and reviewed, and in many respects guided, the work of its 24 sub-committees. These committees carried on their activities through frequent meetings and correspondence and as a result have been very effective in analyzing the research needs in their respective lines which have, in many cases, resulted in the outline of definite research projects. Where it was possible for such projects to be initiated the Technical Advisory Committee cooperated closely with the Director of the Laboratory and cooperating institutions conducting the work.

Of particular interest during the past year has been the consummation of an agreement with the U. S. Navy for conducting a comprehensive cooperative program, and the Executive Committee and Director of the Laboratory have given unstintingly of their time to further the interests of the Government. A study of radiation as a factor in comfort was another new project initiated. This question has been on the Committee's agenda since the publication of the first work on effective temperature. Through the diligent persistence of the entire Committee sufficient special funds were obtained to build and equip, with new and much needed instruments, three structures at the Pittsburgh Laboratory for the investigation of authorized research projects. These structures are now the property of the Society and may be used for other research work when the present programs for which they were built are completed.

The vast scope of Society research and its accomplishments in the past year under the several Technical Advisory Committees follows.

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T. H. URDAHL — B. M. WOODS — C. TASKER

Three Years

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7. *Radiation with Gravity Air Circulation:* M. K. Fahnestock*, *Chairman;* R. E. Daly*, A. G. Dixon, H. F. Hutzel, J. P. Magos, I. W. McElgin, J. F. McIntire, T. A. Novotney, W. A. Rowe.
8. *Heat Transfer of Finned Tubes with Forced Air Circulation:* G. L. Tuve*, *Chairman;* William Goodman, W. E. Heibel, H. F. Hutzel, S. F. Nicoll, R. H. Norris, L. P. Saunders, C. F. Wood.
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12. *Air Distribution and Air Friction:* J. H. Van Alsburg*, *Chairman;* S. H. Downs, M. K. Fahnestock*, R. D. Madison, Axel Marin, L. G. Miller, D. W. Nelson, C. H. Randolph, D. J. Stewart, Ernest Szekely, M. C. Stuart, R. J. Tenkonohy*, G. L. Tuve*.
13. *Heat Requirements of Buildings:* P. D. Close, *Chairman;* W. H. Badgett, E. K. Campbell, J. F. S. Collins, Jr., E. F. Dawson, W. H. Driscoll, H. M. Hart, H. H. Mather, F. B. Rowley, J. H. Walker*.
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17. *Cooling Towers, Evaporative Condensers and Spray Ponds:* B. M. Woods*, *Chairman;* J. C. Albright, S. C. Coey, E. H. Hyde, E. H. Kendall, S. R. Lewis, J. Lichtenstein, J. F. Park, E. H. Taze.
18. *Psychrometry:* F. R. Bichowsky, *Chairman;* D. B. Brooks, W. H. Carrier, H. C. Dickinson, A. W. Gauger, J. A. Goff, William Goodman, A. M. Greene, Jr., L. P. Harrison, F. G. Keyes, D. M. Little, D. W. Nelson, W. M. Sawdon, F. O. Urban.
19. *Corrosion:* A. R. Mumford, *Chairman;* H. E. Adams*, I. F. Barkley, W. H. Driscoll, T. J. Finnegan, W. Z. Friend, R. R. Seeber, F. N. Speller, A. E. Stacey, Jr.*

*Member of Committee on Research.

Sensations of Comfort, 1a

Data which may be considered as a summary of a number of field tests which have been conducted on summer cooling requirements in various localities were presented in the form of a paper at the 1939 Semi-Annual Meeting of the Society. Conclusions based on these tests would seem to indicate that localities having a maximum normal mean summer temperature of 74 F or above should maintain an effective temperature of about 71 deg, while those localities showing normal mean summer temperatures of below 74 F should maintain effective temperatures below 71 deg. Beyond this, some adjustment, probably not to exceed one degree effective temperature, might be based upon peculiar local conditions or peculiarities of the type of occupant.

Investigations are planned for 1940 at the Society Research Laboratory to determine the reactions of subjects to an optimum effective temperature at low relative humidities, and the relation of these reactions to those experienced at the same effective temperatures at high humidities, both as regards feeling of warmth and any other sensations which may be affected.

Physiological Reactions, 1b

It is considered the task of this Committee to present at intervals summaries of current physiological researches and their bearing on ventilation practice. A fairly comprehensive report of this Committee was presented at the 1939 Annual Meeting, and it did not seem advisable to review the subject again during the present year. By 1941 it should probably be possible for the Committee to present another report.

Through a cooperative agreement with the Medical School at the University of Illinois, Chicago, important research studies have been continued on the peripheral type of circulatory failure in experimental heat exhaustion as related to the role of posture of an individual, detailed results of which will be presented at the 1940 Annual Meeting.

Treatment of Disease, 1c

Through a cooperative agreement with the School of Medicine, University of Pittsburgh, work has been continued at the Magee Hospital, to study the application of air conditioning to operating rooms and recovery wards. Investigations this year dealt solely with the bacteriological content of the air in the operating rooms.

Equipment is available at the hospital to clean the air with either a cloth filter, electrostatic precipitator, or air washer. Research is to determine whether these various systems of air cleaning or purification actually decrease the bacteriological content of the air delivered to an operating room. Two methods of taking the samples are being used, first, involving blood agar pour plates to determine the amount of settling bacteria, and the second involves air samples taken by a centrifuge method. An ultraviolet sterile lamp is also being used as a method of bacterial control of the air within the operating room.

This Committee has also concerned itself with the wider application of the use of fever therapy in treating various diseases. Recent reports have indicated that this method of treatment is being used in industrial hospitals with encouraging results.

Climate and Season, 1d

The general objective of this Committee is to study the effect of climate and season on the physiological reactions of human beings, particularly as to their relation to the air conditioning problem. A bibliography has been compiled, which is in the files of the Bureau for Correlating Thermal Research, at the Research Laboratory. Copies may be obtained upon request.

Air Conditioning in Industry, 1e

The program of this Committee for the current year called for determination of the effect of acclimatization to atmospheric environments for different seasons of the year. During the winter months of February and March, some data were collected at the Society's Research Laboratory which showed conclusively that a person gets a greater rise in body temperature and increase in pulse rate due to exposure under the same hot atmospheric environment than is realized during the summer. The shift to a lower effective temperature approximates that between the summer and winter comfort zone, or about 5 deg. The leucocyte count data of February and March might indicate an interesting effect of environmental conditions. The data collected during April show some change; however, not as much as in the case of February and March. A small amount of data were obtained during August to verify the results of the previous summer.

Only a very small amount of work has been done to determine, if possible, any difference in physiological reactions of persons in the same atmospheric environments, but with high and low moisture content. From one test, no material variation in rise of body temperature, or increase in pulse rate was noted. This is the next work on the program of the Committee, as there seems to be some interesting results in connection with the leucocyte count.

Two other points of investigation are being considered: (1) to obtain data on the relative physiological changes of men and women in exposure to hot environments; and (2) to obtain physiological reactions of persons at different rates of activity to atmospheric environments.

Air Pollution and Purification, 2

A great deal of attention has been devoted during the year to the reorganization of this committee. Two excellent groups have been established to deal with the general problems of air pollution and removal of atmospheric impurities. A general meeting of this group was held in New York on December 14 and as an initial program steps were taken to formulate a comprehensive report showing the present status of all knowledge now available covering this subject.

Radiation and Comfort, 3

This Committee was appointed in 1938 to consider all problems relating to radiation as it affects comfort in winter and summer. A comprehensive outline of basic researches was prepared and it was decided to concentrate first on a study to determine the primary sense reactions of relative comfort derived from rooms with normal window arrangements from convected

Contributors to Research

Contributions in support of the research work of the Committee on Research are hereby acknowledged:

Financial Contributions

American Radiator & Standard Sanitary Corp.; Anemostat Corp. of America; Auer Register Co.; Barber-Colman Co.; Buffalo Forge Co.; Carrier Corp.; *Convector Manufacturer's Association;* Detroit Lubricator Co.; W. H. Driscoll; C. A. Dunham Co.; Frick Co., Inc.; G & O Mfg. Co.; Hart & Cooley Mfg. Co.; *Heating, Piping & Air Conditioning Contractors National Association;* Illinois Testing Laboratories, Inc.; Independent Register Co.; Johnson Service Co.; Kewanee Boiler Corp.; Kinetic Chemicals, Inc.; Koppers Co.; McQuay, Inc.; Minneapolis-Honeywell Regulator Co.; Modine Mfg. Co.; Nash Engineering Co.; Owens-Illinois Glass Co.; Philadelphia Electric Co.; John B. Pierce Foundation; Pittsburgh Corning Corp.; Taylor Instrument Cos.; The Trane Co.; U. S. Navy; U. S. Register Co.; Waterloo Register Co.; Westinghouse Electric & Mfg. Co.; Worthington Pump & Machinery Corp.

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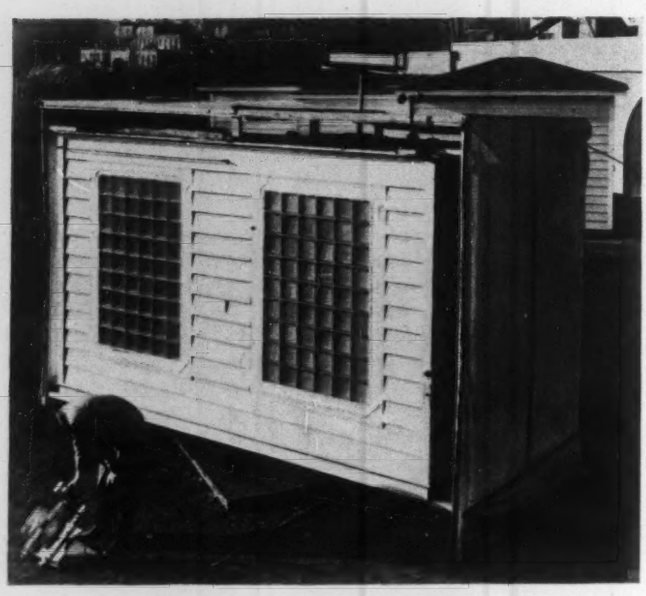


Fig. 1—Test building for determining the solar heat transfer through glass block construction, Research Laboratory

heat and from heat supplied by both convection and direct radiation.

During the summer of 1939 a building was erected at the Society's Research Laboratory in Pittsburgh consisting of two rooms with identical exposures. These rooms have been equipped with the essential apparatus to supply heat and the necessary controlling and measuring devices so that they can be used to carry forward the investigations originally projected by this Committee.

Up to the time of preparing this report only preliminary tests were made for the purpose of observing the equipment. It is the plan of the Committee to carry forward its program of tests as soon as weather conditions in Pittsburgh give consistently cold weather during the daylight hours.

Instruments, 4

This Committee was formed during the early part of 1939 to function as a coordinating group and to study all phases of research dealing with measurements. Due to the great amount of research work now under investigation in various laboratories, it is recognized that a uniform method of measuring thermal environment is desirable and attempts toward standardization in this field is an objective of this group.

Several research projects now being carried on in cooperative institutions dealing with air distribution and air friction require accurate means of calibrating air velocity instruments, and this group is now actively assisting in order that the measurements being taken at various laboratories may be interpreted on a uniform basis. The Committee is also encouraging the development of new instruments applicable to the heating, ventilating and air conditioning industry and in this connection papers presented before the Society in 1939 have indicated the development of several interesting instruments such as a thermocouple psychrometer, a pressure plate anemometer, a radiometer and an absolute hygrometer.

Weather Design Conditions, 5

During the past year the activities of this Committee have been devoted to furthering a means for continuation of the work begun in 1938, especially in determinating climatic differences existing between Weather Bureau. Stations and locations in the center of a city, which are subject to different influences.

The Committee held two meetings in Washington, with officials of the Weather Bureau, and tentative plans have been made for a cooperative research project between the Society and the U. S. Weather Bureau, in establishing a few stations to determine the existing temperature differences between regular stations and city locations.

Transportation Air Conditioning, 6

The Committee has continued this year for the purpose of correlating and consolidating existing material. No special research project was outlined for detailed consideration as it was felt that the main purpose of this group should be to act as a clearing house for the dissemination of data suitable for ship, bus, automobile, aeroplane, and railroad application. In the event that essential research is required the committee feels that it will be its function to suggest the work to be done to fill in present gaps of knowledge.

Radiation with Gravity Air Circulation, 7

Under this committee the work during 1939 has been a continuation of a program in progress for a number of years as a cooperative project with the University of Illinois. The work may be divided into two parts, *first*, that which is being conducted in a warm wall testing booth and, *second*, that which is being conducted in a room heating test plant.

Under the first program standardization tests with steam as a heating medium were completed this year on two light weight cast-iron radiators and on two convectors with cast-iron heating units. These tests were part of a program for standardizing and improving test methods and eventually these same units are to be tested in several different laboratories and the results tabulated and studied.

Under the second study the performance of conventional tubular steam radiators and steam convectors is being studied in a completely remodelled room heating test plant. Three types of direct cast-iron radiators and three types of convectors are being used in these tests with two walls of the test room exposed. It is expected that the results will indicate the effect of size, shape and exposure of the test room upon the performance of

Institutions Cooperating with the Committee on Research

Agricultural & Mechanical College of Texas
Heating Requirements of Buildings

University of California
Performance of Cooling Towers

Case School of Applied Science
Heat Transfer of Finned Tubes with Forced Air Circulation
Air Distribution in Air Conditioned Spaces

University of Illinois, Engineering
Direct and Indirect Radiation with Gravity Air Circulation
Residence Air Conditioning
Air Distribution Outlets

University of Illinois, Medical School
Human Responses to Physiological Reactions

Lehigh University
Frictional Resistance to the Flow of Air Through Elbows

Michigan College of Mining & Technology
Corrosion in Steam Heating Systems

University of Minnesota
Air Cleaning Devices

University of Pennsylvania
Fundamental Theory of Psychrometry

University of Pittsburgh
Air Conditioning Requirements for Hospitals

University of Wisconsin
Effect of Entering Air Temperature and Velocity on Distribution of Air in Enclosed Spaces

tubular steam radiators and convectors and should confirm the correctness of adopted test methods or afford information for improving them.

Heat Transfer of Finned Tubes with Forced Air Circulation, 8

Since the Committee felt that its most important function was correlation and consolidation of existing material, its efforts have been directed toward obtaining an agreement on terminology, fundamental theory, and experimental methods. During the first part of the year an experimental study was carried on at Case School of Applied Science, in which several of the calculation methods for dehumidifying coils were applied to the same sets of test data. These test data were carefully recorded by precision methods and the final result was a surprising agreement between the various methods of computation. Recommendations for a Code for Testing and Rating Fin-Tube Coils have been discussed at some length by the Committee. A memorandum on definitions and one on test methods has been issued for comment.

Cooling Load in Summer Air Conditioning, 9

The activity of this Committee during the past year included the development of plans for a study of the effect of sun radiation on heat gain through building walls. The Research Laboratory built a cubicle having inside dimensions of 18 x 18 ft by approximately 8 ft high. The east, south and west side walls of this building each contained panels of 13-in. brick, 4-in. brick, 8-in. hollow tile, and 4-in. brick veneer on frame construction. The northern exposure differed in that the frame veneer of the construction was eliminated in order to make room for a door.

The roof provided for nine horizontal roof panels all covered with felt and tar waterproofing. These panels included three 2-in. concrete, one 6-in. concrete, two 2-in. plank, one 3-in. tile, one 2-in. gypsum, and one 4-in. gypsum. Provision was made for flooding one of the 2-in. concrete and one of the 2-in. wooden panels. These could be either sprinkled to just keep them wet or flooded with water up to a depth of 6 in. One of the remaining 2-in. concrete panels was finished with the black tar exposed while the others were covered with slag.

The cubicle interior was provided with a cooling facility which with some modification can be converted into a heating system for winter study. Tests were made on several days during part of July and August in which the rates of heat transfer through the inside surfaces of the eleven wall sections and nine roof panels were determined through the 24-hour cycle with the Nicholls' heat flow meter while simultaneous temperatures of the outside surface, inside surface, the outside air, and the inside air and on a number of intermediate points were taken. A great mass of data was accumulated as a result of the summer study giving the simultaneous heat gain through the walls of different construction and exposure.

Solid Fuels, 10

In the first full calendar year since its organization in May 1938, this Committee has actively pursued its functions, namely, the dissemination of available knowledge on equipment and methods for the utilization of solid fuels, the encouragement of research to obtain further knowledge, and investigations to determine the need for codes for testing, and performance of solid-fuel-burning equipment. The work was carried on by extensive correspondence and by three meetings of the Committee, held January 25 in Pittsburgh, April 27 in Primos, Pa., and October 6 in Columbus, Ohio.

The Committee sponsored two research projects during the year. One of these dealt with the performance of domestic chimneys under varying conditions. The second project, in two parts, is being carried on at the Experiment Station of the U. S. Bureau of Mines, Golden, Colorado. One phase of this investigation will include a study of the performance of sub-bituminous coals with residential under-feed stokers, and the second phase of the study covers the performance of these coals in a stoker-fired central heating plant on the campus of the Colorado School of Mines.

Working committees have been appointed by the sub-committees on anthracite, bituminous, and sub-bituminous coal and lignite, to collect information on various types of solid fuel-burning equipment. Also a special sub-committee has been appointed to investigate the need for codes for testing and performance of water heaters fired with solid fuels.

Summer Air Conditioning for Residences, 11

No active research work was conducted under the auspices of this committee during 1939. The committee was continued for the purpose of sponsoring at least one summer's cooling studies in the Research Residence after it was completely insulated in order to compare results from an insulated residence with those from an uninsulated residence. During the summer of 1939 the Research Residence was completely insulated and pending the acceptance of a satisfactory program it is contemplated that a series of tests will be conducted during the summer of 1940 similar to those which were made in 1934 in the uninsulated residence. In that year mechanical refrigeration was used for cooling and both the first and second floors were cooled. At the present time there is some indication that a plan for research in gas summer air conditioning will be initiated in the near future.

Air Distribution and Air Friction, 12

Work outlined by this committee has developed new data this year based on research being conducted at the Society Laboratory and in four cooperative institutions. A paper presented before

Research Papers—1939

Society Laboratory

Summer Cooling Requirements in Washington, D. C., and Other Metropolitan Districts, by F. C. Houghten, Carl Gutberlet and A. A. Rosenberg. (September 1939 JOURNAL.)

Seasonal Variation in Reactions to Hot Atmospheres, by F. C. Houghten, M. B. Ferderber, and A. A. Rosenberg. (Annual Meeting, January 1940).

Factors Affecting Duct Friction, by J. B. Schmieler and H. T. Olson. (Annual Meeting, January 1940.)

Heat Gain Through Glass Blocks by Solar Radiation and Transmittance, by F. C. Houghten, David Shore, H. T. Olson and Burt Gunst. (Annual Meeting, January 1940.)

Cooperative Institutions

Study of Summer Cooling in the Research Residence for the Summer of 1938, by A. P. Kratz, S. Konzo, M. K. Fahnestock and E. L. Broderick. (August 1939 JOURNAL.)

Effect of Size and Type of Air Inlet and Outlet on the Heat Output of Convectors, by A. P. Kratz, M. K. Fahnestock and E. L. Broderick. (September 1939 JOURNAL.)

Cooling Tower Performance Studies, by L. M. K. Boelter. (October 1939 JOURNAL.)

A Standard Air Filter Test Dust, by F. B. Rowley and R. C. Jordan. (October 1939 JOURNAL.)

The Use of Air-Velocity Meters, by G. L. Tuve, D. K. Wright, Jr. and L. J. Seigel. (November 1939 JOURNAL.)

Effect of Lint on Air Filter Performance, by F. B. Rowley and R. C. Jordan. (Annual Meeting, January 1940).

The Peripheral Type of Circulatory Failure in Experimental Heat Exhaustion—The Role of Posture, by R. W. Keeton, F. K. Hick, Nathaniel Glickman and M. M. Montgomery. (Annual Meeting, January 1940).

The Performance of Stack Heads, by D. W. Nelson. (Annual Meeting, January 1940).

Dynamical and Thermal Behavior of Water Drops in Evaporative Cooling Processes, by H. B. Nottage and L. M. K. Boelter. (Annual Meeting, January 1940).

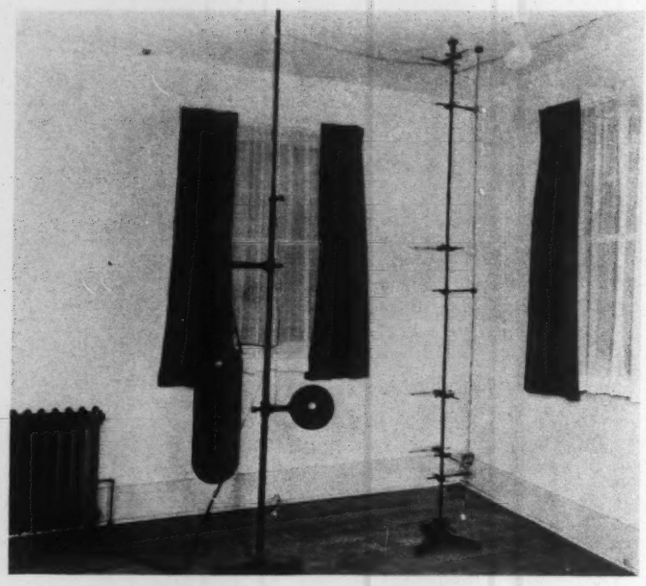


Fig. 2—Thermal integrator and globe thermometer mounted in test room, University of Illinois

the Society in January, 1939 covered the frictional resistance to the flow of air in straight, round and square ducts. Investigations this year have dealt primarily with air flow resistance in rectangular ducts and elbows. All of this program is aimed to complete the Guide tables on duct friction and because of its basic importance will be of tremendous value to the industry.

Cooperative work was initiated at Lehigh University this year to determine the friction of elbows with particular emphasis on the effect of turning vanes and blades. The program at Case School of Applied Science has been planned to determine data on instrument calibration used in air friction and air distribution research and also to determine the nature of the spread of air streams from discharge outlets and the entrainment of room air by such streams. A paper covering stackhead performance is being presented at the Annual Meeting covering cooperative research at the University of Wisconsin during the current year.

The cooperative investigation on air distribution being conducted at the University of Illinois is primarily concerned with the effect of inlet and exhaust opening location on the motion and distribution of air within a room. The tests are being conducted in an experimental room located within a larger insulated enclosure provided with direct expansion refrigeration coils and electric heaters so that control temperatures from 0 to 110 F may be maintained around the outside of the experimental room. Present plans are to determine air distribution with various inlet air velocities ranging from 300 to 1200 fpm when cooling the room under varying conditions.

Heat Requirements of Buildings, 13

Among the problems considered by this committee during 1939 was that relating to the loss of heat through basement floors and walls. In arriving at the heat transmission coefficients for concrete basement floors on the ground, it has been customary to consider only the concrete floor and any other materials in the floor construction, and to neglect any possible heat-resisting effect of any part of the ground on which the floor is located.

It is probable that calculations based on this premise, especially in the case of heated basements, will result in excessive heat losses. However, there appears to be no valid reason that the heat resistance of the floor stops at the under surface of the concrete. On the contrary, it is axiomatic that the heat transfer takes place from a point above the basement floor to a point in the dirt a certain distance below the basement surface where the temperature gradient stops. The intervening dirt will therefore have some heat resistance value. The termination of this temperature gradient will depend on a number of factors including the rate at which heat is dissipated to the ground which in turn, depends on the rate of heat transfer of the ground.

A study of this subject is under consideration for both basement floors and walls below grade and with and without insulation. It is expected that the results of this study will make it possible to check, or perhaps revise, the Guide data on basement heat losses.

Another problem which has been under consideration for some time is that dealing with the selection of temperatures and wind velocities for calculating heat losses. For maximum accuracy, concurring combinations of temperatures and wind velocities should be selected rather than combinations which have no relation to each other. However the solution of this problem is complicated by the fact that the concurring construction which will give the maximum heat loss will depend largely upon the type of structure, especially the relation between the transmission and infiltration losses, because for example, a high wind velocity will not have the same relative effect upon these heat losses in all cases. The problem is further complicated by the fact that the results will vary in each locality. Some progress is being made, however, and it is expected that a satisfactory solution of the problem will be reached at an early date.

Air Conditioning Requirements of Glass, 14

Two meetings of the Committee were held during the past year, one during the Annual Meeting and the other on October 19, in Pittsburgh. The Committee has continued to maintain its own budget and to employ a research engineer at the Society's Research Laboratory. During the past summer the Research Laboratory, in cooperation with the Committee conducted a study on solar heat gain through glass blocks and a paper resulting from this study will be presented at the 1940 Annual Meeting. In conjunction with this study, another investigation on the determination of air to air transmittance values for glass blocks was carried out at the Pittsburgh Testing Laboratory under the supervision of the Committee and the Research Laboratory. A paper resulting from this work will be published in the near future.

The Committee is planning to conduct an extensive research program on the heat transmitting properties of flat glass in single and double glazed units of steel and wood sash. The program may also include a study of the solar heat gain through various heat absorbing glasses, and possibly additional work on condensation.

Insulation, 15

During the year this committee carefully reviewed that portion of THE GUIDE devoted to heat transmission and made pertinent recommendations to the Guide Publication Committee for suggested revision. In view of the development of a new code for testing insulating materials the committee is making recommendations to the Society that a plan be formulated for retesting all insulating materials of current manufacture.

Considerable thought was also given to the causes of condensation in walls and attics of building structures and a chart has been developed showing permissible inside relative humidities to obviate such difficulties based on outside temperatures and type of wall construction.

Sound Control, 16

The primary activity of this committee for the past year has been in connection with the preparation of a standard method for rating apparatus noise. Based on the comments of committee personnel this standard method has been revised and substantial

agreement has been obtaind on most of the provisions. At the present time further activity is hindered by the fact that some development work is necessary on measuring techniques. A method has been outlined for rating the noise from apparatus in open acoustically treated rooms and for measuring noise within a duct system. However, before final recommendations can be made on certain test procedures further research work is necessary.

—A meeting of the committee was held in New York on May 17 and recommendations were made for conducting an investigation on the nature of noise transmission in duct systems without the use of absorbent lining but no suitable location could be determined for conducting the tests. A tentative program was also outlined by the committee for studying the relation of various physical factors in sound to their annoyance but this work has also been held in abeyance due to lacking laboratory facilities and funds to support the project.

Cooling Towers, Evaporative Condensers and Spray Ponds, 17

Work has been continued at the University of California this year through a cooperative agreement with the Society to study the fundamental properties of cooling tower design. A paper on the performance of cooling towers was presented at the 1939 Semi-Annual Meeting and a report is now being completed covering an analytical study of drop dynamics which will be available for the Annual Meeting.

During the past year, preliminary computations have been made on the absorption of solar radiation by means of water films of various thicknesses. Tests have been made giving results of air-liquid surface heat exchangers in which the air side is wetted by means of water. Also observations have been made on free convection from an atmospheric tower and data have been obtained giving the pressure drop of air-foil packed towers, the latter of which will be correlated with heat transfer and mass transfer results. Plans for determination of drop size distribution from jets, characteristics of drift particles, rates of growth and decay of water particles, are progressing. The Committee is also interested in enlarging all of these studies to include some problems of evaporative condensers and roof cooling.

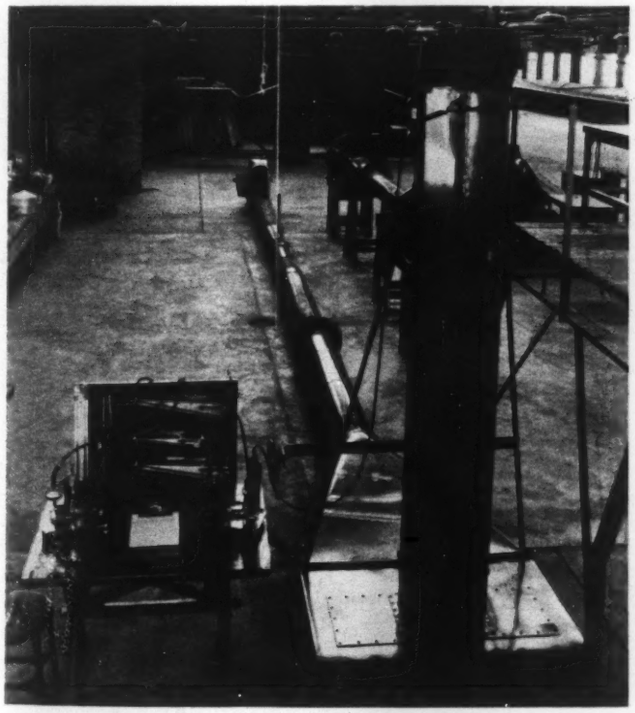


Fig. 3—Testing equipment for determining performance of stack heads, University of Wisconsin

Fig. 4—Method of traversing air streams from discharge outlets, Case School of Applied Science

Psychrometry, 18

The major activity of the Committee is an exact determination of the thermodynamic properties of air-water vapor mixtures. Since the laws of combination of air and water vapor deviate from the perfect gas laws by an amount which is of the order of one per cent, this work, of necessity, dictates accurate experimental investigations. A theory has been developed which is based upon statistical mechanics on the theoretical side and on available data on the equations of state of air and steam on the practical side. The next step is the experimental testing of the theory which is being done under a cooperative agreement with the University of Pennsylvania. The final apparatus is now being constructed and assembled for conducting the investigations. At the request of the Guide Publication Committee, the Committee supervised the redrawing of the Bulkeley Psychrometric Chart to make it consistent with Table 6 in Chapter 1 of THE GUIDE and to improve its accuracy and make it simpler to read.

Corrosion, 19

Activities of a former research committee dealing with corrosion in air conditioning systems were transferred to this committee during the 1939 Annual Meeting. The major research project planned for investigation this year dealt with the determination of the amount of non-condensable gases that will dissolve in the condensate formed in a heating system at different rates of condensation. This work was being studied through a cooperative agreement at the Michigan College of Mining and Technology but was interrupted during the summer by a disastrous fire. The Committee authorized the continuation of the project and the contributors agreed so steps are now being taken at the College to re-equip a new laboratory.

R. A. MacArthur and S. R. Lewis Address Cincinnati Meetings

November 14, 1939. The November meeting of the Cincinnati Chapter was called to order by Pres. H. E. Sproull at the Netherland Plaza Hotel with 35 members and guests in attendance.

W. H. Junker read the minutes of the previous meeting which were approved as read. R. E. Kramig then introduced the speaker of the evening, R. A. MacArthur, research engineer, Lockland, O., who gave an interesting blackboard talk on sound, and through the use of scientific instruments and equipment demonstrated actual measurements of sound levels, etc. He also chased the poor little decibel around the room for the instruction and amusement of the members and guests, after which many questions were forthcoming.

Mr. Kramig reported on the activities of the Membership Committee and Treasurer Junker gave his report on the financial status of the Chapter. O. W. Motz advised that he would report on the smoke code in 30 days. Following a favorable report by President Sproull on the Fall Meeting of the Society in Atlanta, the meeting was adjourned.

October 19, 1939. President Sproull conducted the regular monthly meeting at the Netherland Plaza Hotel which was attended by 42 members and guests.

The Membership Committee reported that a goal of 20 new members had been set for 1939-1940.

O. W. Motz, chairman of the Legislative Committee, agreed to submit a report on the status of the new proposed smoke code of the City of Cincinnati at the November meeting.

S. R. Lewis, Chicago, through the courtesy of the Speakers' Bureau of the Society, was the guest speaker and was introduced by President Sproull. Mr. Lewis in his human and distinct manner unraveled the mysteries of heating, air conditioning and piping, which was followed by a general discussion. Mr. Lewis' talk was not only extremely interesting, but educational, and after an enthusiastic vote of appreciation the meeting was adjourned.

Southern California Meets

November 14, 1939. The regular monthly meeting was held at the Royal Palms Hotel, Los Angeles, and the members and guests heard Dr. Huntington give an informal talk on air conditioning from the physician's viewpoint. He discussed the various types of illnesses that are affected by temperature, humidity and air impurity and expressed the opinion that air conditioning would take an important part in conjunction with medicine in improving the health of the people.

The guest speaker of the evening was Mr. Ufer from the Fire Underwriters' Laboratory, who gave an interesting talk, describing several types of fires that had occurred in air conditioning systems, such as burning filters and burning duct linings. He also showed that air motion could increase and spread fires and described devices for limiting and extinguishing fires. Mr. Ufer also talked about the use of Underwriters' Laboratory labels on manufactured air conditioning units, which was followed by adjournment.

October 11, 1939. Pres. J. F. Park called the October meeting to order at the Royal Palms Hotel, and during coffee time T. J. Cunningham, attorney, spoke on the need for the election of competent men to the State Legislature, and urged that citizens contact the legislators and express their viewpoints.

The principal speaker of the evening was Roy Van Meter, who addressed the meeting on the subject of cross connections in plumbing systems. Mr. Van Meter described the many ways in which city water supply systems could be polluted by the introduction of impure water in the complex piping systems of private buildings. He also showed the need for cooperation from all engineers in preventing these cross connections. The meeting was adjourned at 9:00 p.m.

September 12, 1939. The Southern California Chapter opened its fall season with the September meeting held at the Royal Palms with President Park presiding.

Following the introduction of the new Chapter officers President Park announced the following committees:

Program—A. J. Hess, chairman; W. D. Fabling.
Code—Glenn Miller, Arthur Theobald and O. W. Ott.
Research—H. L. Eggleston, chairman; H. M. Hendrickson.
Membership—E. H. Kendall.
Publicity—Harrold English.
Speakers' Bureau—J. B. Griffith.

President Park reported on the tentative program of the meetings scheduled for the coming season.

Mr. English then introduced the guest speaker of the evening, W. M. Goodman, La Crosse, Wis., who gave an interesting presentation on the dehumidification of air with coils. The ratio of sensible to total heat removed by a coil was shown to be a function of the entering air conditions and the surface temperature of the coil. Mr. Goodman's talk was followed by a discussion before the meeting adjourned.

Pittsburgh Nominates Officers

November 13, 1939. The regular monthly meeting which was attended by 50, was called to order by Vice Pres. F. C. McIntosh at the Grant Building Restaurant, and the minutes of the previous meeting were read and approved.

Following the reports by the various committee chairmen F. C. Houghten spoke on the success of the Fall Meeting of the Society held in Atlanta, Ga.

F. B. Mahon reporting for the Nominating Committee announced the following for officers to serve Pittsburgh Chapter in 1940:

President—F. C. McIntosh; *Vice-President*—E. C. Smyers; *Secretary*—T. F. Rockwell; *Treasurer*—L. S. Maehling. *Board of Governors*—R. A. Miller, *chairman;* R. J. J. Tennant and G. G. Waters.

Mr. McIntosh introduced Walter L. Fleisher, second vice-president and chairman of the Research Committee of the Society, who spoke on the significance of air conditioning research for human beings.

Following Mr. Fleisher's talk Dr. M. B. Ferderber, University of Pittsburgh, was introduced and gave a brief talk on the possible effects on humans of exposure to high temperature, which was followed by adjournment at 10:30 p.m.

October 9, 1939. Pres. R. A. Miller called the October meeting to order at Stouffer's Restaurant with 25 members and guests present. The minutes of the May meeting were approved as read.

Following the report by Treas. L. S. Maehling, F. C. McIntosh and C. M. Humphreys entertained the members and guests with stories of their trip to and from Mackinac Island.

G. G. Waters, chairman of Program Committee outlined the programs for the November and December meetings.

The following were appointed to serve on the Nominating Committee: P. A. Edwards, chairman; B. R. Small and F. B. Mahon.

President Miller delegated the Executive Committee to draft a plan for the use of the chapter funds now reserved for convention purposes.

At the suggestion of P. Nicholls, President Miller called upon all members and guests present to answer two questions. The first, what subjects each one is prepared to discuss before the chapter; and the second, what subjects would they prefer to hear?

The ensuing discussion occupied the remainder of the evening, the accumulated notes being turned over to the Program Committee before the meeting adjourned at 10:30 p.m.

Philadelphia Chapter Hears Drinker and Fleisher

November 9, 1939. The regular monthly meeting of the Philadelphia Chapter was held at the Engineers Club, and 61 members and guests were in attendance for dinner and 75 present for the meeting immediately following.

Pres. R. F. Hunger called the meeting to order and the minutes of the previous meeting were read and approved, including the Treasurer's report. C. B. Eastman, chairman of the Membership Committee introduced new members, and Lee P. Hynes spoke about the Eastern Air Conditioning Conference at Lehigh University.

H. B. Hedges, chairman of the Meetings Committee, gave advance information concerning the December and January meetings, which was followed by a report by W. A. Bornemann who presented the following names of members who will serve on the Nominating Committee: W. F. Smith, *chairman;* F. D. Mensing, L. C. Davidson, L. E. Moody and H. H. Erickson.

Mr. Hedges then introduced the speaker of the evening, Philip Drinker, professor of Industrial Hygiene, Harvard School of Public Health, who gave an interesting talk on air pollution, and held the attention of his audience for over an hour. The meeting was adjourned at 9:30 p.m.

October 12, 1939. Held at the Engineers Club, the October meeting was called to order by President Hunger with 60 members and guests in attendance.

Following a brief talk on the Red Cross Drive by L. F. Floge, the minutes of the previous meeting were approved as read, together with the report of the Treasurer.

A short address was made by A. V. Hutchinson, secretary of the Society, in which he called attention to the Fall Meeting of the Society in Atlanta, Ga., on October 30 and 31.

H. B. Hedges gave a brief preview of meetings for the coming season and then introduced the speaker of the evening, W. L. Fleisher, New York, second vice-president and chairman of the Research Committee of the Society, who gave a very interesting talk on the significance of air conditioning research for human beings. A short discussion followed and the meeting was adjourned at 9:45 p.m.

Oregon Holds First Meeting

November 8, 1939. The first regularly scheduled meeting of the Oregon Chapter of the Society was held at the Imperial Hotel, Portland, with 24 members and guests present.

Glenn Stanton, president of the local chapter of the *American Institute of Architects,* principal speaker of the evening, discussed the trend of modern architecture. Mr. Stanton lamented the modern idea of renovating old fire-traps instead of tearing down the building and rebuilding. He further stated that on his recent trip through the United States he noticed that the architecture on the Pacific Coast was on a par with that in the East.

Following Mr. Stanton's address Pres. J. D. Kroeker called for reports of all standing committees, which were received and accepted.

An interesting discussion followed when E. E. Carroll suggested that the Chapter write to the City Council asking if the city intended to enforce the City Code with respect to the weight of metal to be used in warm air furnaces. The subject was referred to the legislative Committee for a complete investigation of the problem, and its report should suggest a possible course for the Chapter.

There being no further business, President Kroeker declared the meeting adjourned.

Western New York Chapter Meets

November 13, 1939. Twenty-one members and guests attended this meeting at the University Club with Acting President C. A. Gifford presiding.

Joseph Davis and D. J. Mahoney were appointed to make arrangements for the Christmas Party held December 18 at the University Club. M. C. Beman then gave an interesting report of the Society's Fall Meeting which was held in Atlanta, Ga.

Harold Epstein of the Buffalo Sewer Authority was introduced by Mr. Gifford and addressed the group on Buffalo's Sewage System. A rising vote of thanks was given Mr. Epstein after which the meeting was adjourned.

October 9, 1939. The Western New York Chapter held its first meeting of the current season at the University Club with 29 members and guests attending.

After the reading of the May minutes which were approved as corrected it was suggested by Joseph Davis that the Chapter have a formal winter party in February similar to the affair held a few years ago. It was agreed that plans were to be made and presented to the Chapter at a later date.

C. W. Farrar presented an interesting report on the Summer Meeting of the Society held at Mackinac Island, Michigan. After completion of this report Vice-Pres. Gifford introduced M. C. Beman, speaker of the evening. Mr. Beman spoke on the subject of Buffalo's New Civic Buildings. The meeting adjourned after a rising vote of thanks was given Mr. Beman for his interesting and instructive talk.

L. G. Miller and F. C. Houghten Lecture at Western Michigan

November 13, 1939. The November meeting of the Western Michigan Chapter of the Society was held at the Burdick Hotel, Kalamazoo, with 53 members and guests in attendance. Pres. B. F. McLouth called the meeting to order and after a roll call

Oregon Chapter Officers

J. Donald Kroeker
President

T. E. Taylor
Vice-President

H. B. Nielsen
Treasurer

C. E. Heinkel
Secretary

by the secretary, minutes of the October meeting were read and approved.

A resolution was passed to send flowers to C. A. Simonds, who was ill, as a token of respect from the Western Michigan Chapter. S. W. Todd was delegated to put this resolution into effect.

President McLouth then introduced the first speaker of the evening, Prof. L. G. Miller, head of department of mechanical engineering at Michigan State College, who gave a discussion on the air change vs. crack method of calculating heat loss by infiltration. Professor Miller gave the pros and cons of each method, stressing in particular the unreliability of both, but he did believe that the crack method gave the more uniform results.

Following Professor Miller was Ivan Anderson, contractor, who gave an illustrated talk on the relative merits of weather stripping and calking in its application to the home. He also gave a discussion regarding the different types and kinds of materials and their applications in weather stripping, giving at the same time the cost data pertaining thereto, which was well received.

The last speaker of the evening was G. W. Alexander, Libbey-Owens-Ford Co., who covered the merits and application of storm sash and double glazing. He presented a short discussion covering the fuel savings and comforts that were gained in storm sash and double glazing. He concluded his discussion with a presentation of some of the new glass products being produced and their advantages, which was followed by adjournment.

October 2, 1939. There were 40 members and guests in attendance for the monthly dinner and meeting of the Western Michigan Chapter held at the Browning Hotel, Grand Rapids.

Pres. B. F. McLouth called the meeting to order and the minutes of the annual chapter meeting held May 24, 1939 were read and approved. The personnel of the standing committees was announced and reports from the various officers were then discussed. A resolution was made and passed to the effect that the meetings would continue to be held on the second Monday of each month from October until May, unless otherwise found necessary, in which event the officers may change any meeting date to accommodate their program.

The speaker of the evening, F. C. Houghten, Director of the Society's Research Laboratory, was then introduced. Mr. Houghten gave a brief word-picture of the progressive steps of the Laboratory relating to the methods by which projects were accepted and the magnitude to which some may and have grown with intellectual thinking. He also gave the current interests at the Laboratory as well as at institutions working in cooperation with the Society. Mr. Houghten followed his brief historical lecture with slides on the relation of man to his atmospheric environment in which he traced the advance in the Laboratory's research in attempting to establish some laws or physical ideals and ideas upon which future activities can be based. An interesting question and answer period followed and the meeting adjourned at 10:30 p. m.

Atlanta Meetings

October 3, 1939. The regular monthly meeting of the Atlanta Chapter was held at the Cox-Carlton Hotel, and was attended by 18 members and guests.

Following the report of the Treasurer, C. E. Brockinton reported for the Membership Committee, which was followed by the report of the Entertainment and Program Committee given by F. L. Laseter.

The Nominating Committee announced that the candidates for Chapter Officers were as follows: *President,* T. T. Tucker; *Vice-President,* S. W. Boyd; *Secretary,* L. F. Kent; *Treasurer,* L. L. Barnes; and *Board of Governors,* E. W. Klein and C. L. Templin.

Mr. Kent gave a very clear explanation of progress since the last meeting in connection with the Fall Meeting of the Society in Atlanta. The chairmen of all committees under Mr. Kent made reports and answered questions brought up at the meeting.

H. N. Casell, director of the Dale Carnegie Institute, gave an exceptional talk based on sales psychology. The appreciation of his talk on the human side of selling was evidenced by the active questioning in the discussion that followed. A rising vote of thanks was extended to Mr. Casell, after which the meeting was adjourned.

September 6, 1939. The September meeting of the Atlanta Chapter, held at the Biltmore Hotel, had 16 members and guests in attendance. The minutes of the previous meeting were approved as read.

President Templin discussed the advisability of securing new members, and stressed the fact that the Atlanta Chapter should be composed of more men from the professional and educational fields.

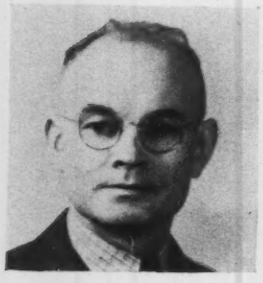
The Treasurer reported on the financial condition, which was followed by a brief discussion on the program and entertainment for the Fall Meeting of the Society held in Atlanta, Ga. L. F. Kent, general chairman of the Committee on Arrangements for this meeting, delivered a report on the progress of the various committees, and recommendations and suggestions from the floor were discussed and agreed upon.

Manitoba Meetings

September 21, 1939. The regular monthly meeting of the Manitoba Chapter was held at the Fort Garry Hotel, Winnipeg, with Pres. G. C. Davis presiding. Following the reading of the minutes of the previous meeting, which were approved as read, Secy. Ivan McDonald was instructed to write to the various committee chairmen confirming the appointment of committee members. A letter from E. K. Campbell, Kansas City, chairman of the Society's Membership Committee, was then read and turned over to J. B. Steele for attention.

President Davis then introduced the speaker of the evening, A. A. Paoli, Vulcan Iron Works Ltd., who gave an interesting address on reaction of the mining industry in Canada to the

Oregon Board of Governors



E. E. Carroll

C. M. MacGregor

F. F. Urban

second World War, which he illustrated with a moving picture and sound effects. P. L. Charles expressed the appreciation on behalf of the Society to Mr. Paoli, and adjournment followed.

August 24, 1939. A business meeting of the Chapter was held at the Concordia Club, Winnipeg, and was called to order by President Davis. The minutes of the June 1 meeting were read and approved on motion of D. F. Michie and P. L. Charles.

Following the reading of a letter from the Speakers' Bureau for the coming year the Committee chairmen and members were appointed as follows:

Membership—J. B. Steele, chairman; E. F. Munn and Frank Thompson.

Research and Publicity—R. L. Kent, chairman; Ledyrad Avery and Ivan McDonald.

Educational Committee—P. L. Charles, chairman; William Worton.

June 1, 1939. A special meeting of the Manitoba Chapter was held at the Concordia Club, Winnipeg, which was a special business meeting only. The meeting was called to order by President Davis, and following the reading of the minutes of the previous meeting, the Treasurer's Report was received and read.

After some discussion relative to the definition of air conditioning as requested by the Toronto Board of Trade, it was agreed on motion of Messrs. Steele and Kent that a copy of the file on this subject be forwarded to the Toronto Chapter of the Society in order to obtain their comments before communicating further with the Board of Trade.

Mr. Steele, chairman of the Membership Committee, gave a brief report on the year's activities and the possibility of securing new members.

The secretary read a letter from H. R. Eade, expressing his regret at not being able to attend more of the Chapter meetings due to unforseen circumstances, and requesting that the Chapter accept his resignation as Treasurer. It was moved and seconded that Mr. Eade's resignation be accepted with the regrets of the Chapter.

It was then agreed on motion that E. J. Argue be appointed to the Board of Governors to fill the vacancy created by the resignation of Mr. Eade.

On motion of Messrs. Michie and Avery it was agreed that the Chapter headquarters should be changed from the Fort Garry Hotel to the Concordia Club, and this was followed by adjournment.

W. L. Fleisher Guest at St. Louis

October 5, 1939. Dinner was served at the Kingsway Hotel preceding the October meeting of the St. Louis Chapter which was a joint meeting with the Engineers Club of St. Louis, and was attended by 156 members and guests.

Walter L. Fleisher, New York, N. Y., Second Vice-President of the Society, before presenting his subject, discussed membership activities and suggested the sources of membership and urged that eligible men be invited to join. Following this Mr. Fleisher gave an interesting talk on the significance of air conditioning research for human beings, which brought about a worthwhile discussion before adjournment.

September 12, 1939. The first meeting of the season was held at the Kingsway with 22 in attendance, and J. H. Carter welcomed the members and guests.

After the various Committee chairmen reported, C. E. Hartwein introduced M. F. Carlock, who ably discussed the paper on A Study of Summer Cooling in the Research Residence for the Summer of 1938, which was presented before the Society at its 1939 Semi-Annual Meeting, Mackinac Island, Mich. This was followed by a lively discussion and numerous questions were answered by Mr. Carlock.

Pres. R. J. Tenkonohy then discussed the activities of the Society's Research Committee.

Kansas City

The first meeting of the Kansas City Chapter 1938-39 season was held in *October 1938* and had 27 members and guests present. Albert Buenger, as speaker of the evening, covered the many ramifications of air conditioning and its status at the present time.

The *November* meeting was held in collaboration with that of the *American Institute of Architects* and the members and guests were fortunate in having three speakers. A. W. Archer spoke on State registration of architects and engineers, Nate W. Downes, chief engineer and superintendent of buildings for Kansas City, addressed the meeting on the engineers' viewpoint in relation to architects, and William L. Cassell joined in with his ideas on the same topic.

J. L. Harrington spoke at the *December* meeting on government spending during the depression.

The *January 1939* meeting had S. R. Lewis, Chicago, as guest speaker, who chose the unusual aspects of complete air conditioning as his subject.

The *February* meeting was devoted to a discussion on the modern methods of weather forecasting.

H. L. Hutchinson addressed the *March* meeting on development in the lighting field.

At the *April* meeting L. T. Mart gave an interesting talk on the advances in the design of cooling towers.

The *May* meeting brought the 1938-39 season to a close. Dr. Charles Sheard, Mayo Clinic, Rochester, Minn., presented an instructive talk on the thermal exchanges between the body and its atmospheric environment.

Oklahoma

The first meeting of the 1938-39 season of the Oklahoma Chapter of the Society was held at the Skirvin Hotel, Oklahoma City, *October 10, 1938.* The speaker of the evening was H. J. Clark, Oklahoma Inspection Bureau, who gave an interesting presentation on the relation of the air conditioning business to the underwriter.

The *November* meeting was held in the Electric Bungalow of the Oklahoma Gas & Electric Co., with A. G. Dixon, Modine Mfg. Co., as the guest speaker. Mr. Dixon spoke on the design of heating and air conditioning equipment from the manufacturer's viewpoint.

The *December* meeting, also at the Electric Bungalow, had Carl F. Boester as the speaker of the evening. Mr. Boester's visit was arranged through the Speakers' Bureau of the Society, and his subject was on the application of storage refrigeration to air conditioning. The meeting was well attended.

S. R. Lewis, past president of the Society and former chairman of the Committee on Research, gave an interesting talk at the *January 1939* meeting. Mr. Lewis spoke on the unusual aspects of complete air conditioning, reviewing the designs of a series of air conditioning plants and analyzing their performance for the design condition and for different types of occupancy and use. He also discussed zoning methods, the use of well water for pre-cooling and condensing purposes, the influence of illumination, odor elimination, and duct and damper design.

The *February* meeting had Prof. E. F. Dawson, University of Oklahoma, and A. G. Stejskal, Binks Mfg. Co., as speakers. Professor Dawson spoke on the highlights of the 45th Annual Meeting of the Society, while Mr. Stejskal presented a discussion on cooling towers, illustrated by slides. There were 29 members and guests present at this meeting.

Albert Buenger, chairman of the Guide Publication Committee of the Society, spoke at the regular *March* meeting on the present status of the air conditioning industry. On *March 29* there was a special meeting at the Skirvin Hotel, and Pres. J. F. McIntire was the guest. President McIntire addressed the chapter on the birth of air conditioning and its future.

The annual meeting of the Oklahoma Chapter was held on *May 8* at the Electric Bungalow with Mark E. Mooney, Carrier Corp., Syracuse, N. Y., presenting a talk on evaporative con-

densers. At this final meeting of the season the officers for 1939-1940 were elected as follows:

President—A. A. Hoppe
Vice-President—R. G. Dolan
Secretary—S. L. Rolland
Board of Governors—R. E. Pauling, Roy L. Patton and Earle W. Gray.

The committees appointed to serve for the coming season are as follows:

Membership—Earle W. Gray, chairman; E. F. Dawson and A. R. Morin.
Standards and Codes—S. L. Rolland, chairman; R. G. Dolan and F. X. Loeffler.
Meetings—J. M. Mideke, Earle W. Gray and E. F. Dawson.
Research Representative—J. H. Carnahan.

Northern Ohio

The *September 1938* meeting of the Northern Ohio Chapter was the first meeting of the 1938-39 season, and was held at the Aurora Country Club, where the members and guests, numbering 21, enjoyed golf and dinner.

All the meetings during the past year have been held at the Cleveland Club with dinner preceding each meeting.

Pres. J. F. McIntire was the guest at the *October* meeting, which was attended by 41 members and guests. President McIntire outlined the Society work for the 1940 Annual Meeting to be held in Cleveland in January 1940.

The *November* meeting had Prof. C. P. Yaglou, Harvard School of Public Health, representative of the Speakers' Bureau, who delivered an address on the health aspects of air conditioning. There were 75 in attendance at this meeting.

Heat transfer by use of extended surface was the topic discussed at the *December meeting*, which had an attendance of 72 members and guests. William Goodman, La Crosse, Wis., presented the subject discussed.

The *January 1939* meeting had F. J. Kurth, New York, as speaker of the evening. Mr. Kurth chose air diffusion as his topic for discussion at the meeting, which was attended by 54 members and guests.

The *February* gathering was devoted to a dinner-dance at the Shaker Tavern, with 50 members and guests attending.

The subject discussed at the *March* meeting was presented by Prof. G. L. Larson, University of Wisconsin, representing the Speakers' Bureau, who selected mechanical systems of hot water heating as his topic. The attendance at this meeting was 63 members and guests.

The *April* meeting, with an attendance of 42, had Randolph Eide as speaker of the evening. Mr. Eide presented an interesting talk on the telephone business today, illustrating his remarks.

Dehumidification and its place in industrial air conditioning was the subject of discussion at the *May* meeting and was presented in an interesting manner by F. R. Bichowsky, Ann Arbor, Mich. The attendance was 40 at this meeting, which was the final one of the season.

Interest in the subjects brought before the Northern Ohio Chapter members during the year evidenced lively discussions. A spirit of good fellowship has prevailed and the Chapter is looking forward to increased membership as a result of the activity incidental in the Society's Annual Meeting in January 1940.

Prof. Giesecke Visits Ontario —Dust Control Discussed

November 28, 1939. The regular monthly meeting for December, advanced to this date, was held at the Royal York Hotel with 54 members and guests in attendance to hear Prof. F. E. Geisecke deliver an address before the Ontario Chapter.

Following dinner the minutes of the previous meeting were accepted as read. Pres. H. D. Henion announced that steps were being taken by the Building Department of the City of Toronto to make a new building code. H. H. Angus represented the Ontario Chapter at a recent meeting of the Building Department, and the members were urged to attend the next meeting of the department to express their views in the matter.

An announcement was made of the Air Conditioning School Conference at the University of Minnesota, December 4-6.

President Henion then introduced the guest of the evening, Prof. F. E. Giesecke, College Station, Tex., first vice-president of the Society and professor of heating, ventilating and air conditioning at the Agricultural and Mechanical College of Texas, who gave an illustrated talk on hot water heating and panel heating and cooling applications. An interesting discussion followed Professor Giesecke's talk, and E. Holt Gurney extended a vote of thanks to him for his instructive and enlightening address.

November 6, 1939. Eighty members and guests were present at the regular Ontario Chapter meeting, which was held at the Royal York Hotel, Toronto. The previous minutes were accepted as written and the secretary read a letter from A. J. Dickey, past-president of the Ontario Chapter, and convalescing in Toronto Western Hospital, who expressed his appreciation for the flowers sent him by the Chapter.

Pres. H. D. Henion announced that the regular December meeting had been advanced to November 28, at which time Prof. F. E. Giesecke, first vice-president of the Society, was to address the Ontario Chapter.

President Henion announced that the City of Toronto's new building code is incorporating the code for steam and hot water heating for residences up to 50,000 cu ft capacity, and also is including the warm air code which was prepared by Ontario Chapter members.

The speaker of the evening, P. J. Dunlop, Hollinger Consolidated Gold Mines, was then introduced, and presented an illustrated talk on Dust Control at the Hollinger Mines. Mr. Dunlop's address was of extreme interest to the members and guests and brought forth an active discussion. A vote of thanks was extended to Mr. Dunlop by S. W. Alexander on behalf of the Chapter, which was followed by adjournment.

October 2, 1939. The opening meeting of the season was held at the Royal York Hotel with 59 members and guests present.

Following dinner President Henion outlined the activities for the coming year and extended a welcome to all members for a very active season.

M. W. Shears made a report on the Code Committee, followed by an announcement by J. H. Fox, chairman of the Program Committee, of the speakers for the various meetings during the coming year. President Henion then announced the committees and their chairmen who will act during the year 1939-1940, and C. Tasker was appointed as the Ontario Chapter's representative to the Affiliated Engineering and Allied Societies in Ontario.

It was moved by D. O. Price and seconded by H. B. Jenney that the secretary get in touch with M. Barry Watson, Registrar for Professional Engineers, in regard to having the Society members listed as a group in the Professional Engineers bulletin.

President Henion then presented a certificate of appreciation of the Chapter for services to the following past presidents of the Ontario Chapter: Messrs. M. F. Thomas, H. H. Angus, A. S. Leitch, H. R. Flett, A. J. Dickey, R. W. McHenry, E. B. Sheffield, M. Barry Watson, H. J. Church, H. S. Moore, J. S. Wood, W. P. Boddington, W. R. Blackhall, M. W. Shears, Thomas McDonald, G. A. Playfair and H. B. Jenney.

The president then called upon O. Lloyd Maddux, formerly a member of the Ontario Chapter, but now located in New York. Mr. Maddux spoke briefly expressing his appreciation at being able to return to Toronto and visit his friends in the Chapter.

W. R. Blackhall presented some very interesting colored slides on the World's Fair and resort scenes in Ontario, which was followed by adjournment.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 40 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by January 16, 1940, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
AHRENS, C. F., Sales, R. A. Dubuque Supply Co., St. Louis, Mo.	R. M. Rosebrough E. C. Kuntz	J. J. Blackmore J. S. Rosebrough
ALTEMUELLER, G. F., Chief Engr., Homeland Investment Co., Durham, N. C.	W. M. Wallace, II H. L. McDowell	T. C. Cooke A. G. Syska
BARNES, H. S., Sales Engr., American Blower Corp., Charlotte, N. C.	C. E. Petty H. H. Hill	F. H. Brandt, Jr. W. M. Wallace, II
BARNES, W. L., Sales Engr., The H. L. Thompson Co., Houston, Tex.	D. S. Cooper C. A. McKinney	A. B. Banowsky C. G. Crocker *(Non-Member)*
BECKER, S. J., Sales Engr., J. Becker, Inc., Montreal, Que., Can.	Harold Gittleson G. L. Wiggs	C. W. Johnson J. R. Dupuis *(Non-Member)*
BISPALA, J. T., Htg. Engr., Bispala Bros., Hibbing, Minn.	F. W. Legler J. R. Hall	I. C. Davidson H. M. Betts
CONKLIN, R. M., Engr., The Fred D. Pfening Co., Columbus, Ohio.	A. I. Brown R. A. Sherman	S. R. Beitler *(ASME)* F. W. Marquis *(ASME)*
COTT, W. B., Air Cond. Engr., The Doermann-Roehrer Co., Cincinnati, Ohio.	E. J. Richard E. B. Royer	Charles Bird H. E. Sproull
DOUGLAS, D. C., Tech. Sales Engr., United Equipment & Supply Co., Washington, D. C.	I. T. Fisher T. H. Urdahl	P. H. Erisman, Jr. F. A. Leser
FUNK, D. S., Pres., National Standard Air Prod. Co., Chicago, Ill.	G. B. Tupper S. I. Rottmayer	A. O. May M. W. Bishop
GRAHAM, J. J., Mgr. Htg. & Plbg. Dept., Montgomery Ward & Co., Chester, Pa.	J. M. Kipe P. F. Leffler *(Non-Member)*	R. S. Lafferty *(Non-Member)* J. B. Taylor *(Non-Member)*
HAMILTON, H. S., Co-Partner, Air Correction Co., Milwaukee, Wis.	C. H. Randolph T. M. Hughey	J. H. Volk J. S. Jung
HOOVER, W. L., Sales Engr., Clarage Fan Co., Washington, D. C.	Glegge Thomas T. H. Urdahl	F. A. Leser W. H. Littleford
KIRTLAND, E. M., Dist. Repr., Mueller Brass Co., Milwaukee, Wis.	J. S. Jung J. H. Volk	C. H. Randolph T. M. Hughey
KLAGES, F. E. P., Dist. Mgr., The Powers Regulator Co., Greensboro, N. C.	H. C. Mueller A. L. Crump	A. J. Keating C. A. Gustafson
KOENIG, A. C., Sales Engr., Evansville, Ind.	J. E. Maynard James Crombie	C. E. Johnson R. D. Kelley
LAIR, P. H., Cons. Engr., Newton Center, Mass.	C. P. Yaglou Philip Drinker	H. M. Tarr T. B. Knight *(Non-Member)*
LATTERNER, HENRY, JR., Sales Engr., McCrea Equipment Co., Washington, D. C.	K. F. Baldwin P. H. Loughran, Jr.	E. V. Fineran A. E. Stack
LEE, B. H., Serviceman, Consolidated Edison Co., New York, N. Y.	S. E. Dibble M. C. Giannini	P. B. Gordon A. C. Coonradt *(ASME)*
LEIBY, R. S., Contractor & Designer, Columbus, Ohio.	H. R. Allonier A. W. Williams	J. P. Oelgoetz L. T. Avery
MCGINNIS, F. L., Mech. Engr., Williamsburg Restoration, Inc., Williamsburg, Va.	H. I. Schulz F. B. Campbell	H. A. Lockhart M. C. Gillett
MCNAMEE, E. W., Design Engr., B. & J. Jacobs Co., Cincinnati, Ohio.	W. H. Junker G. V. Sutfin	H. E. Sproull R. E. Kramig, Jr.
MOHSIN, SHAWKI, Air Cond. Engr., Carrier Corp., Syracuse, N. Y.	R. V. D. Dunne L. L. Lewis	H. S. Traynor W. B. Rorison *(ASRE)*
MUMFORD, A. R., Assoc. Dir. of Research, Consolidated Edison Co. of New York, New York, N. Y.	J. H. Walker D. S. Boyden	J. F. Collins, Jr. W. L. Fleisher
MYER, HAYDN, Pres., Haydn Myer Co., Inc., Birmingham, Ala. *(Reinstatement & Advancement)*	C. P. Lichty H. C. Gause	F. L. Hardy J. G. Trawick
NAMAN, I. A., Houston, Tex.	C. A. McKinney D. S. Cooper	W. H. Severns J. H. Pound *(ASME)*

CANDIDATES

NORTH, W. R., Sales Engr., Baltimore, Md.

ORMISTON, J. B., Owner, Ormiston Plbg. & Htg. Co., Yonkers, N. Y.

PARKINSON, J. S., Acoustical Engr., Johns-Manville Research Labs., Manville, N. J.

PLOSKEY, E. J., Engr., Redwood Mfrs. Co., San Francisco, Calif.

PORTER, K. C., Engr., Commonwealth Edison Co., Chicago, Ill.

POUGHER, B. R. E., Engr., Ernest W. Pougher & Son, Manchester, England.

RAINSON, SAMUEL, Htg., Vtg. & Cooling Mechanic, Great Neck, L. I., N. Y.

SIPP, E. F., JR., Engr., Mills Novelty Co., Chicago, Ill.

SMITH, R. C., Design Engr., York Ice Machinery Corp., St. Louis, Mo.

SNOOK, A. H., Mfrs. Agent, Kalamazoo, Mich.

SNYDER, E. F., JR., Htg. Engr., Biek Heating Supply Co., Dowagiac, Mich.

STEPHENSON, J. R., Sales Engr., J. R. Stephenson & M. M. Perry, Winnipeg, Man., Can.

THEISS, E. S., Instructor, Mech. Engrg., Duke University, Durham, N. C.

WEISS, W. G., Sales Mgr., St. Louis Furnace Mfg. Co., St. Louis, Mo.

REFERENCES

Proposers	*Seconders*
A. C. Crawford	T. H. Urdahl
E. J. Febrey	W. H. Littleford
W. R. Zuhlke	E. N. Sanbern
O. O. Oaks	H. G. Meinke
W. L. Fleisher	C. H. B. Hotchkiss
A. E. Stacey, Jr.	John James
E. W. Simons	L. H. Cochran
T. J. White	C. E. Bentley
C. M. Burnam, Jr.	C. E. Price
H. G. Chapin	H. J. Prebensen
Walter Yates	E. W. Pougher
H. H. Jennins	S. P. Howden *(Non-Member)*
M. I. Blumenthal	O. W. Ott
E. P. Wells	W. L. Holladay *(ASRE)*
J. C. Peebles *(ASME)*	W. S. Bodinus *(ASME)*
Daniel Roesch *(ASME)*	C. G. Anderson *(Non-Member)*
L. J. DuBois	A. G. Matousek
E. B. Cover	W. A. Siegel
W. H. Schlichting	S. H. Downs
C. R. McConner	K. L. Ziesse
C. R. McConner	W. G. Schlichting
G. D. Woodhouse	J. S. Cunningham
J. B. Steele	William Worton
D. F. Michie	Ivan McDonald
F. J. Reed	W. M. Wallace, II
T. C. Cooke	H. L. McDowell
B. C. Simons	M. F. Carlock
E. C. Kuntz	W. J. Oonk

CANDIDATES ELECTED

In the past issues of the JOURNAL of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Committee on Admission and Advancement and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. B-III, Sec. 8, of the By-Laws, the following list of candidates elected:

MEMBERS

BEAIRD, B. J., Resident Engr., Kribs & Landauer, Houston, Tex.

BELL, S. R., Cons. Engr., Sydney R. Bell & Associates, Melbourne, Australia

BERRY, R. U., Dist. Mgr., Air Cond. Dept., General Electric Co., Dallas, Tex.

BOESTER, C. F., Air Cond. Engr., Marlo Coil Co., St. Louis, Mo. (*Advancement*)

DENHAM, H. S., Malden, Mass.

DILLENDER, E. A., Htg. Engr., Houston Gas & Fuel Div. of United Gas Corp., Houston, Tex.

DOWDY, R. B., Sales Engr., Haydn Myer Co., Inc., Montgomery, Ala.

ESPENSCHIED, F. F., Sales Engr., American Air Filter Co., Washington, D. C.

EVANS, W. A., Dist. Mgr., Aerofin Corp., Cleveland, Ohio. (*Reinstatement*)

FINNIGAN, W. T., Sr. Partner, Finnigan Bros., Portland, Ore.

GAMBLE, C. B., Engr., Leo S. Weil & Walter B. Moses, New Orleans, La. (*Advancement*)

GRITZAN, L. L., Vice Pres. & Gen. Mgr., United Equipment & Supply Co., Washington, D. C.

HERSH, F. C., Specialty Engr., Penna. Power & Light Co., Allentown, Pa. (*Advancement*)

JONES, L. K., Mgr., Special Test Section, Pittsburgh Testing Lab., Pittsburgh, Pa.

LOCKE, J. S., Sales Engr., Minneapolis-Honeywell Regulator Co., Chicago, Ill.

MCCULLOUGH, J. L., Asst. Br. Mgr., National Radiator Corp., Pittsburgh, Pa. (*Reinstatement*)

PATTERSON, G. P., Engr., W. H. Sullivan Co., Greensboro, N. C.

POWERS, E. C., Sr. Partner, E. C. Powers & Son, Philadelphia, Pa.

SCOTTI, F. D., Tech. Dir., G. de Micheli & C., S. A., Florence, Italy

SHUMAN, Laurence, Mech. Engr., U. S. Housing Authority, Washington, D. C.

SKAGERBERG, Rutcher, Sr. Mech. Engr., U. S. Housing Authority, Washington, D. C. (*Reinstatement*)

WESTENDARP, F. G., Mgr., Guinard Freres, Caracas, Venezuela

ASSOCIATES

CHASE, R. E., Pres., R. E. Chase & Co., Inc., Tacoma, Wash.

GUEST, P. L., JR., Sales Engr., Hoffman Specialty Co., Greensboro, N. C.

HARBERGER, G. L., Mgr., Peerless Htg. Div., The Eastern Foundry Co., Boyertown, Pa.

MCCANN, F. D., Dist. Supvr., Westinghouse Elec. & Mfg. Co., New York, N. Y.

RICHARDS, G. H., Mgr., Htg. Dept., Crane Co., Birmingham, Ala.

ROGERS, T. L. C., Managing Dir. & Chief Engr., National Air Cond. Co., Ltd., London, Ont., Can.

WIDMER, W. J., Secy-Treas., Widmer Plbg. & Htg. Co., Inc., Portland, Ore.

JUNIORS

BRISSENDEN, C. W., Htg. Engr., Portland General Electric Co., Portland, Ore.

DAVIS, D. W., JR., Sales Engr., B. F. Sturtevant Co., Greensboro, N. C.

DRUM, L. J., JR., Sales Engr., York Ice Machinery Corp., Birmingham, Ala.

MORTON, P. S., Sales Engr., Automatic Htg. & Cooling Supply Co., Chicago, Ill.

RAY, G. E., Engr., William A. Scherff, Union, N. J.

SEIGEL, L. J., Test Engr., Cleveland Elec. Illuminating Co., Cleveland, Ohio

SILVERA, AMERICO, Engr., Refrig. Dept., Viana's Auto Supply, San Nicholas, Aruba, N. W. I.

WALDEN, H. K., Secy., Haydn Myer Co., Inc., Birmingham, Ala.

STUDENT

TOULOUKIAN, YERAM, Grad. Student, Mass. Inst. of Tech., Cambridge, Mass.

Heating · Piping and Air Conditioning

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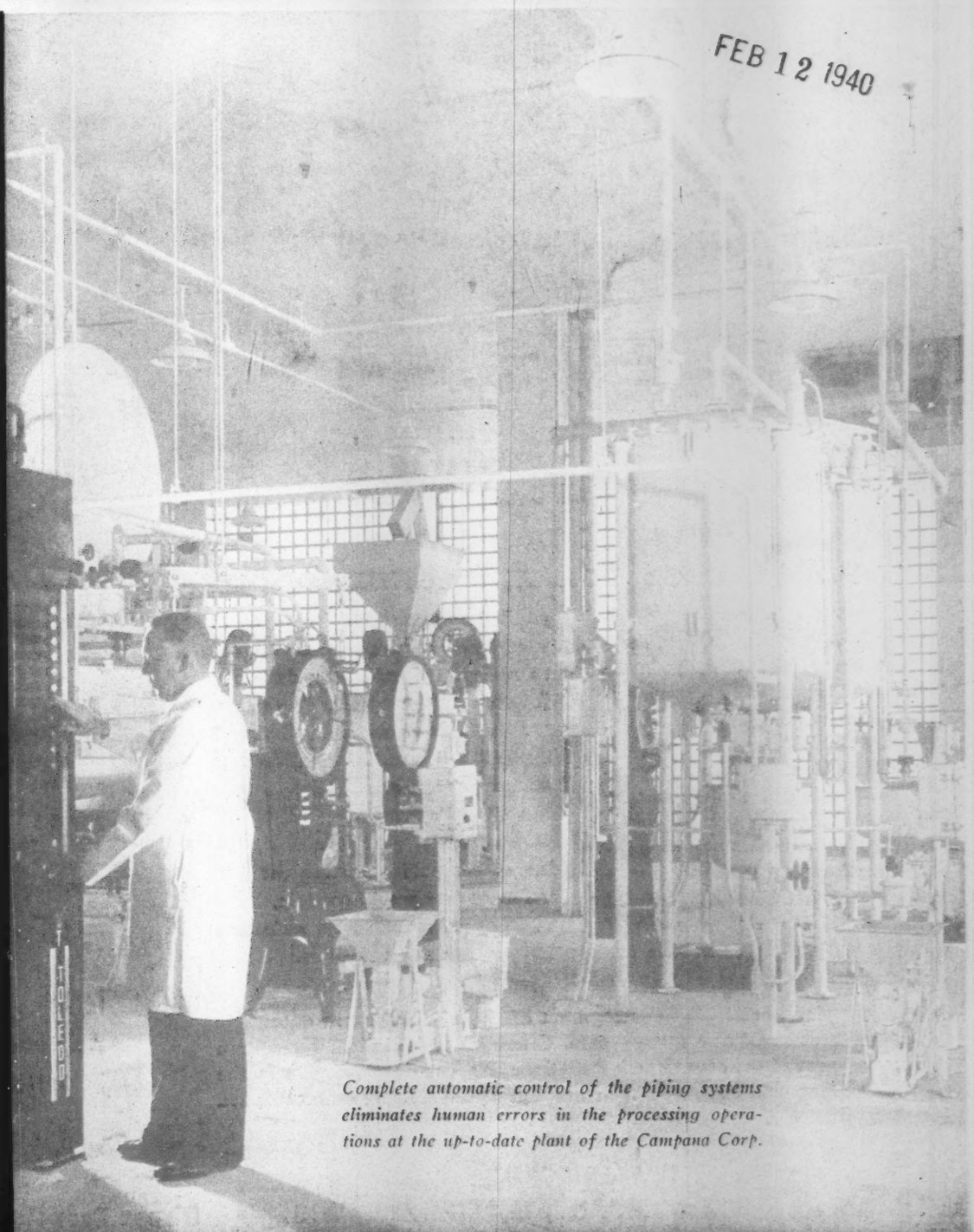

Complete automatic control of the piping systems eliminates human errors in the processing operations at the up-to-date plant of the Campana Corp.